U.S. Consumer Product Safety Commission
LOG OF MEETING

SUBJECT: PGMA Technical Summit on Carbon Monoxide (CO) Hazard Mitigation for Portable Generators

DATE OF MEETING: 17 March 2016

LOG ENTRY SOURCE: Joel Recht, Engineering Sciences

DATE OF LOG ENTRY: 25 March 2016

LOCATION: Embassy Suites, BWI, Linthicum Heights, MD

ATTENDEE(S): See attached.

SUMMARY OF MEETING:

- PGMA provided background information on research they've done on root cause analysis and efforts such as their "Take it outside" educational and outreach program. CPSC staff provided background information on the CO hazard from portable generators as well as developments for low CO emission generators and automatic shutdown technologies, while other presenters discussed improvements to weather resistance for generators, various specific technologies for reducing emissions or sensing CO, as well as for the development of a low CO emission portable generator and the success achieved in the marine generator market which now has requirements for low CO emission generators. (See attached agenda and slides.)
- A brainstorming session was held where participants discussed thoughts and concerns including the durability of sensors used to automatically shut down a generator (for the life of the generator), needs and challenges related to weatherizing generators such that they could be used in the rain to address a scenario where people might take one indoors to avoid rain, opportunities to improve warning labels, to require product registration in order to receive an activation code to use a generator, to require retailers to provide safety information and have consumers acknowledge receipt, to require voice-chip warning with 2-step startup in order to establish acknowledgement of warning prior to start, various potential action limits for CO warnings, and improved targeting of information and educational campaigns("I&E"), such as through social media and by working with utility providers to urge them to notify their customers at times of shutoff of service. When question was raised about which firms are close to market with any of the ideas discussed, Techtronic Industries said they could bring their low CO emission generator to market in 2017. No other firms disclosed any potential future marketing. Suggestions for improved I&E included targeting of utility companies, commissions and NGO's for low income utility subsidies, targeting messaging with hurricanes, including through other agencies like FEMA.
- PMGA stated that their next steps after the Summit would include some revision to their voluntary standard, PGMA 300, at some point in the future, as well as PGMA considering the proceedings of the Summit to eventually develop a roadmap for performance-based standards to address CO hazards, as well as continuing to work with UL on their UL2201 task groups.
- Agenda, attendee list, additional notes and presentations are attached.

TECHNICAL SUMMIT AGENDA
EMBASSY SUITES, BWI
FRIENDSHIP BALLROOM

Thursday, March 17, 2016
8:00 AM - 4:30 PM Eastern Time

7:30 - 8:00 AM	Badge Pick-Up/Registration	
8:00 - 8:15 AM	Introductions and Overview of the Day	Susan Orenga, Executive Director, PGMA
8:15 - 8:45 AM	Background on PGMA Efforts and Research	Susan Orenga, Executive Director, PGMA
8:45 - 9:15 AM	Statement of the Challenges and Root Cause Analysis	Greg Wischstadt, SVP Global Product Management, Generac Power Systems
9:15 - 9:30 AM	**BREAK**	
INNOVATIVE IDEAS PRESENTATIONS		
9:30 - 9:50 AM	CPSC Staff Technical Research to Address the Carbon Monoxide Hazard for Portable Generators	Dr. Joel R. Recht, Associate Executive Director, Directorate for Engineering Sciences, U.S. Consumer Product Safety Commission
9:55 - 10:15 AM	CO and Boating: The NIOSH Experience	Captain Ronald M. Hall, MS, CIH, CSP, NIOSH
10:20 - 10:40 AM	Carbon Monoxide Sensing Technology Overview	Peter Hsi, MS, Ph.D., Honeywell
10:45 - 11:05 AM	TTI Proposal	Michael Gardner, Vice President, New Product Development, Techtronic Industries
11:10 - 11:30 AM	GenTent Safety Canopies, Keeping Families Safe by Weatherproofing Portable Power	Mark Carpenter, Owner/Inventor, GenTent Safety Canopies
11:30 AM -12:00 PM	**LUNCH BREAK**	
INNOVATIVE IDEAS PRESENTATIONS CONTINUED		
12:00 - 12:20 PM	Catalyst Control of CO from Portable Generators	Kevin Hallstrom, Heavy Duty Technical Service and Regulatory Affairs Manager; BASF Corporation – Global Catalysts Division
12:25 - 12:45 PM	KWJ Engineering: Advanced Solutions for Generator Safety	Ed Stetter, KWJ Engineering / SPEC Sensors
12:50 - 1:10 PM	6 Recommendations for Preventing Carbon Monoxide Poisonings and Deaths Caused by Portable Generators	Albert Donnay, MS, MHS Consulting Detoxicologist
1:15 - 1:30 PM	**BREAK**	
1:30 - 3:45 PM	Brainstorming Session	Moderator: Roger Gault, Truck & Engine Manufacturers' Association
3:45 - 4:30 PM	Closing Remarks and Next Steps	

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MEETING SUMMARY
Portable Generator Manufacturers Association

TECHNICAL SUMMIT
Thursday, March 17, 2016
8:00 a.m. - 4:30 p.m. Eastern Time

EMBASSY SUITES, BWI
BALTIMORE, MD

ATTENDANCE

PGMA Representatives

Dean Hartley	American Honda Motor Co., Inc
Michael Rudolph	American Honda Motor Co., Inc.
Sarah Somorai	American Honda Motor Co., Inc.
Mike Derra	Briggs & Stratton Home Power Products, LLC
Patricia Hanz, Vice President	Briggs & Stratton Home Power Products, LLC
Greg Marchand	Briggs & Stratton Home Power Products, LLC
Scott Stefaniak	Champion Power Equipment
Kevin Cole	Generac Power Systems
Rob Brimble	Generac Power Systems
Greg Wischstadt	Generac Power Systems
David Versfelt	PGMA Legal Counsel / K&L Gates
Joe Harding	PGMA / Thomas Associates, Inc.
Susan Orenga	PGMA / Thomas Associates, Inc.
George Brandon	Techtronic Industries Power Equipment
Michael Gardner	Techtronic Industries Power Equipment
Lee Sowell	Techtronic Industries Power Equipment
Mark Rowe	Techtronic Industries Power Equipment
Robert Motl	Wacker Neuson Production Americas LLC
Daniel Schlepp	Wacker Neuson Production Americas LLC
Dave Park	Yamaha Motor Corp USA
Tom Pugh	Yamaha Motor Corp USA

Others

Kevin Hallstrom	BASF
Albert Donnay	Donnay Detoxicology & Environmental Health Engineering
Roger Gault	EMA
Mark Carpenter	GenTent Safety Canopies, LLC
Simon Doughty, Ph.D.	Heraeus Precious Metals North America, LLC
Peter Hsi	Honeywell
Carol Pollack-Nelson	Independent Safety Consulting
Ed Stetter	KWJ Engineering
Dr. Rasto Brezny	Manufacturers of Emission Controls Association (MECA)
Charon McNabb	National Carbon Monoxide Awareness Association

Capt Ronald Hall	National Institute for Occupational Safety and Health (NIOSH)
Steven Emmerich	National Institute of Standards and Technology
Gerry Coons	OPEI
Greg Knott	OPEI
Ed Krenik	Policy Resolution Group, Bracewell LLP
Nick Schmal	Reliance Controls Corporation
Ken Boyce	UL
Charles Smith	U.S. Consumer Product Safety Commission
Joel Recht	U.S. Consumer Product Safety Commission
Mark Kumagai	U.S. Consumer Product Safety Commission
Matthew J. Brookman	U.S. Consumer Product Safety Commission
Barbara Little	U.S. Consumer Product Safety Commission
Sarah Klein	U.S. Consumer Product Safety Commission
- Chief Counsel to Commissioner Robert Adler	
Jacqueline Campbell	U.S. Consumer Product Safety Commission
Commissioner Joe Mohorovic	U.S. Consumer Product Safety Commission
Ryan Radford	U.S. Consumer Product Safety Commission
Gib Mullan	U.S. Consumer Product Safety Commission
- Commissioner Buerkle's Office	

PRESENTATIONS

Background on PGMA Efforts and Research	Susan Orenga, Executive Director, PGMA
Statement of the Challenges and Root Cause Analysis	Greg Wischstadt, SVP Global Product Management, Generac Power Systems
CO and Boating: The NIOSH Experience	Captain Ronald M. Hall, MS, CIH, CSP, NIOSH
Carbon Monoxide Sensing Technology Overview	Peter Hsi, MS, Ph.D., Honeywell
TTI Proposal	Michael Gardner, Vice President, New Product Development, Techtronic Industries
GenTent Safety Canopies, Keeping Families Safe by Weatherproofing Portable Power	Mark Carpenter, Owner/Inventor, GenTent Safety Canopies
Catalyst Control of CO from Portable Generators	Kevin Hallstrom, Heavy Duty Technical Service and Regulatory Affairs Manager; BASF Corporation – Global Catalysts Division
KWJ Engineering: Advanced Solutions for Generator Safety	Ed Stetter, KWJ Engineering / SPEC Sensors
6 Recommendations for Preventing Carbon Monoxide Poisonings and Deaths Caused by Portable Generators	Albert Donnay, MS, MHS Consulting Detoxicologist

BRAINSTORMING SESSION

The following list of ideas were generated during the Brainstorming Session. GMA Board of Directors and Technical Committee will review and next steps will be shared accordingly.

1. After a consumer registers a portable generator, can information be emailed or can they be directed to a mobile app for safety information.
2. Heat resistant exhaust pipe
3. Use of a long exhaust pipe (similar to marine generator "stacks").
4. Proximity Sensors (that detects if the unit is indoors (i.e. a certain amount of space from a wall or ceiling or possibly outside and too close to a wall)
5. Atmosphere sensors
6. Two-step sequence that requires user acknowledgement that the portable generator is outdoors or with a voice activated "Take it Outside" message.
7. Compare the air at near the exhaust vs. near the generator to determine if it is in an enclosed space.
8. Checklist with purchase (do you have appropriate cords, weather protection, etc.). Ensure checklist has photos and is in English and Spanish.
    a. In addition a coupon for sensors, CO alarm, cords
9. Add the "Take it Outside" logo/information to the box and to the Generator.
10. "Quick Start Guide" that includes "Take It Outside" information.
11. Develop an O2 sensor that would identify what is normal and if it deviates from normal by a certain amount to "abnormal" the sensor goes off (would need to be generator specific)
12. Require that a "fob" be inserted into the unit for starting. This fob can then be removed and worn by someone during use - the fob would have a built-in CO alarm.
13. Monitor air-to-fuel ration and shut down if "out of range".
14. Develop a performance-based standard (vs. a design-based standard).
15. Ensure there is a menu option of solutions for manufacturers to choose from.
16. Back-Up sensor with primary sensor
17. Use of redundant systems
18. CO sensor that could determine if the unit is indoors vs. outdoors (CO should diffuse in the outdoors faster)
19. Develop standards for weather resistance
20. Wheel lock and motion alarm for theft deterrence
21. Partner to add a "Take it Outside" message about generator safety to the weather alert system
22. Directed web advertising or "Take It Outside" messages to anyone searching online for portable generators.
23. Google/Social media - If people are searching for generators on Google, work to ensure a message comes up next time they are on Facebook.
    a. Paid search for portable generators
24. Put a QR code on the product for registration and to enable first time use (could be sent to Take it Outside site)
25. Educate Big Box retailers
    a. Regulation for signature/acknowledgement of hazard when purchasing (cigarettes, cold medicine, etc.)
26. Provide incentives or somehow force customers to register their portable generators before using them.
27. When someone buys a GenTent Safety Canopy and registers, part of the auto response could be a link to the take it Outside campaign.
28. Work with State Fire Marshalls on safety awareness messages (NH currently has one for generators)
29. Research non-profits who subsidize utility bills and work with them on safety messages
30. National Center for Environmental Health (CDC) partnership
31. HUD offices of Healthy Homes partnership
32. FEMA partnership
33. Develop an additive that causes odor and ensure generator doesn't work without the additive.
34. Develop a generator with a smaller engine that doesn't run as long

35. Require that the size of the fuel tank is related to CO emissions.
36. Put ribbons in front of exhaust to show where the hazard is.
37. Put skull and cross bones danger symbol near the exhaust.
38. Add portable generator safety information to utility disconnection notices.

Respectfully Submitted,

THOMAS ASSOCIATES, INC.

(This summary was reviewed by PGMA Legal Counsel prior to distribution)

SO/JH/jlb
pgma
3/23/16

PGMA Technical Summit

March 17, 2016

1300 Sumner Avenue
Cleveland, OH 44115-2851
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Agenda

- Introductions
- Portable Generator Manufacturers' Association (PGMA) history
- Background / Research
- PGMA current/future work on promoting safe use of portable generators
- PGMA's Initial Brainstorm on Potential Technical Solutions
- Technical Challenges/Next Steps

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REMINDERS FROM PGMA LEGAL COUNSEL

This Summit has gathered together representatives of competitors and others for the worthy purposes of education and discussion. Some simple antitrust guidelines for the day:

1. There can be NO discussion of any specifics about pricing.
2. There can be NO discussion aimed at forcing a point of view by means of a refusal to deal.
3. While it is often beneficial to seek consensus, there can be NO industry demand that all manufacturers adhere to particular positions.

GOAL FOR TODAY: EDUCATION

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About PGMA

- The Portable Generator Manufacturers' Association (PGMA) is a trade association 501 (c) (6) that seeks to develop and influence safety and performance standards for our industry's products. Formed in 2009, PGMA members include the major manufacturers of portable generators sold in North America and a significant majority of the industry.

Members:	
American Honda Motor Company	Techtronic Industries Power Equipment
Briggs & Stratton Power Products Group LLC	Wacker Neuson Production Americas LLC
Champion Power Equipment	Yamaha Motor Corp USA
Generac Power Systems	

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Background

- 2000 – Several current PGMA members join ANSI standard making process for UL 2201.
- 2002 – First draft of UL 2201
- 2003 – CPSC warning language to accompany generators proposed.
- 2003 – 2007 – UL 2201 standard making activities stall with several unresolved issues.
- 2005 – 2013 – CPSC Testing/Demonstration of a Remote Carbon Monoxide Sensing Automatic Shut-Off Device and a Low Carbon Monoxide Emission Portable Generator
- 2007 – Final rule for the required warning label on portable generators is published in the Federal Register.
- 2009 – UL publishes UL 2201 (Standard for Portable Engine-Generator Assemblies) as a non-ANSI UL standard without consensus.

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Background / Research

- CPSC Reports
  - Annual – Incidents, Deaths, and In-Depth Investigations Associated with Non-Fire Carbon Monoxide from Engine-Driven Generators and Other Engine-Driven Tools, 2004-2014
  - 2013 – Investigating the Utility of Global Positioning System (GPS) Technology to Mitigate the Carbon Monoxide (CO) Hazard Associated with Portable Generators – Proof of Concept Demonstration

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Background / Research

- NIST Reports
  - 2009 – Technical Note 1637: Modeling the Effects of Outdoor Gasoline Powered Generator Use on Indoor Carbon Monoxide Exposures
  - 2010 – Technical Note 1666: Modeling the Effects of Outdoor Gasoline Powered Generator Use on Indoor Carbon Monoxide Exposures – Phase II
  - 2013 – Technical Note 1781: Modeling and Measuring the Effects of Portable Gasoline Powered Generator Exhaust on Indoor Carbon Monoxide Level
  - 2013 – Technical Note 1782: Residential Carbon Monoxide Exposure due to Indoor Generator Operation: Effects of a Source Location and Emission Rate
  - 2014 – Technical Note 1834: Development of a Test Method to Determine Carbon Monoxide Emission Rates from Portable Generators

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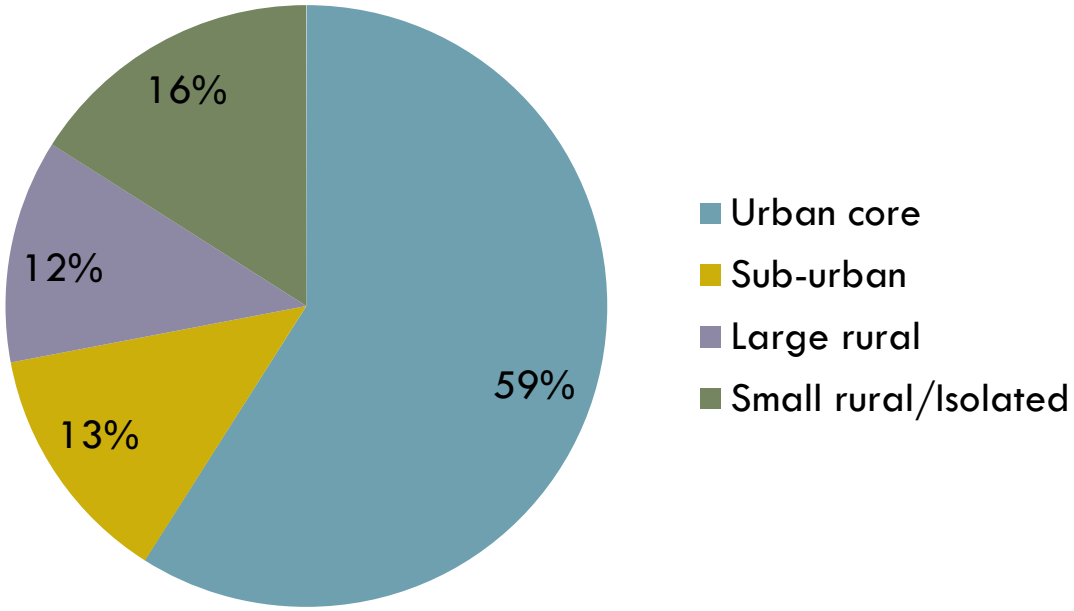
Fatalities Associated with Generators, - By Population Density, 2004-2014



Source: U.S. Consumer Product Safety Commission, Directorate for Epidemiology, 2015
WWAMI Rural Research Center at the University of Washington Economic Research Group, USDA
U.S. Census Bureau, 2011

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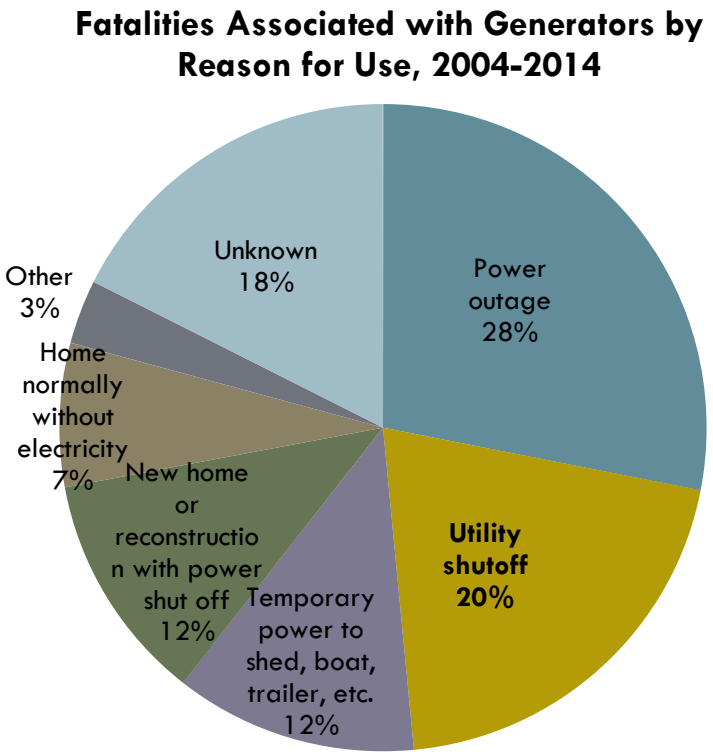
Background / Research

- CPSC study* on reported fatalities due to carbon monoxide poisoning found that the second most common reason for portable generator use was due to power shut off by utilities, accounting for 20 percent of the reported deaths.
- PGMA worked with NARUC on their adoption of CA-1 Resolution, recognizing the importance of educating consumers on Portable Generator Carbon Monoxide Safety (2013). Follow-up attempts to ensure utilities are sharing safety information on their websites and through consumer notifications has been challenging.
- As part of the new "Take it Outside" safety awareness campaign, PGMA sending safety letter to utilities across the country urging them to send out safety information with shut off notifications.



*Incidents, Deaths, and In-Depth Investigations Associated with Non-Fire Carbon Monoxide from Engine-Driven Generators and Other Engine-Driven Tools, 2004-2014", written by Matthew V. Hnatov of CPSC.

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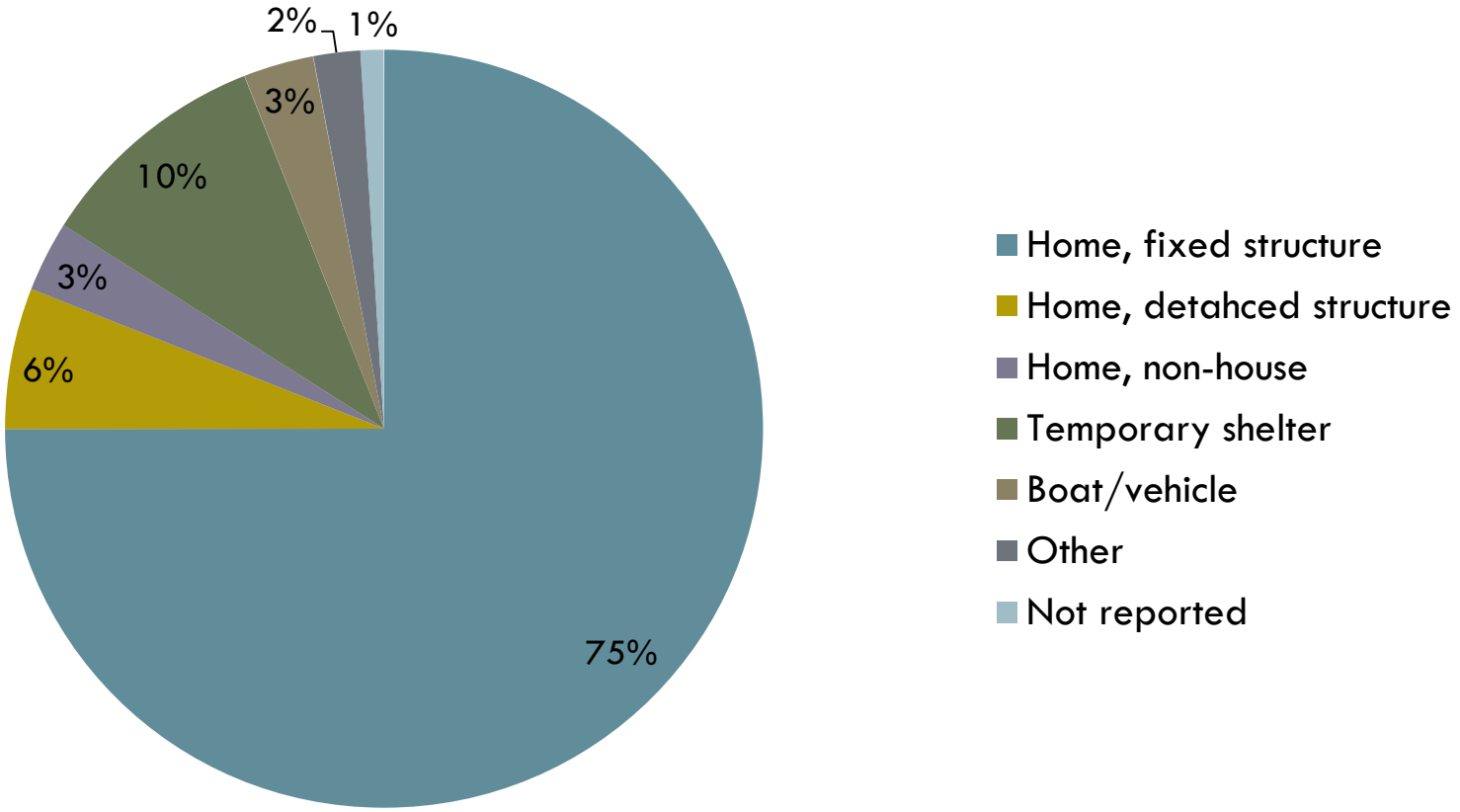
Fatalities Associated with Generators, by Location, 2004-2014



Source: U.S. Consumer Product Safety Commission, Directorate for Epidemiology, 2015

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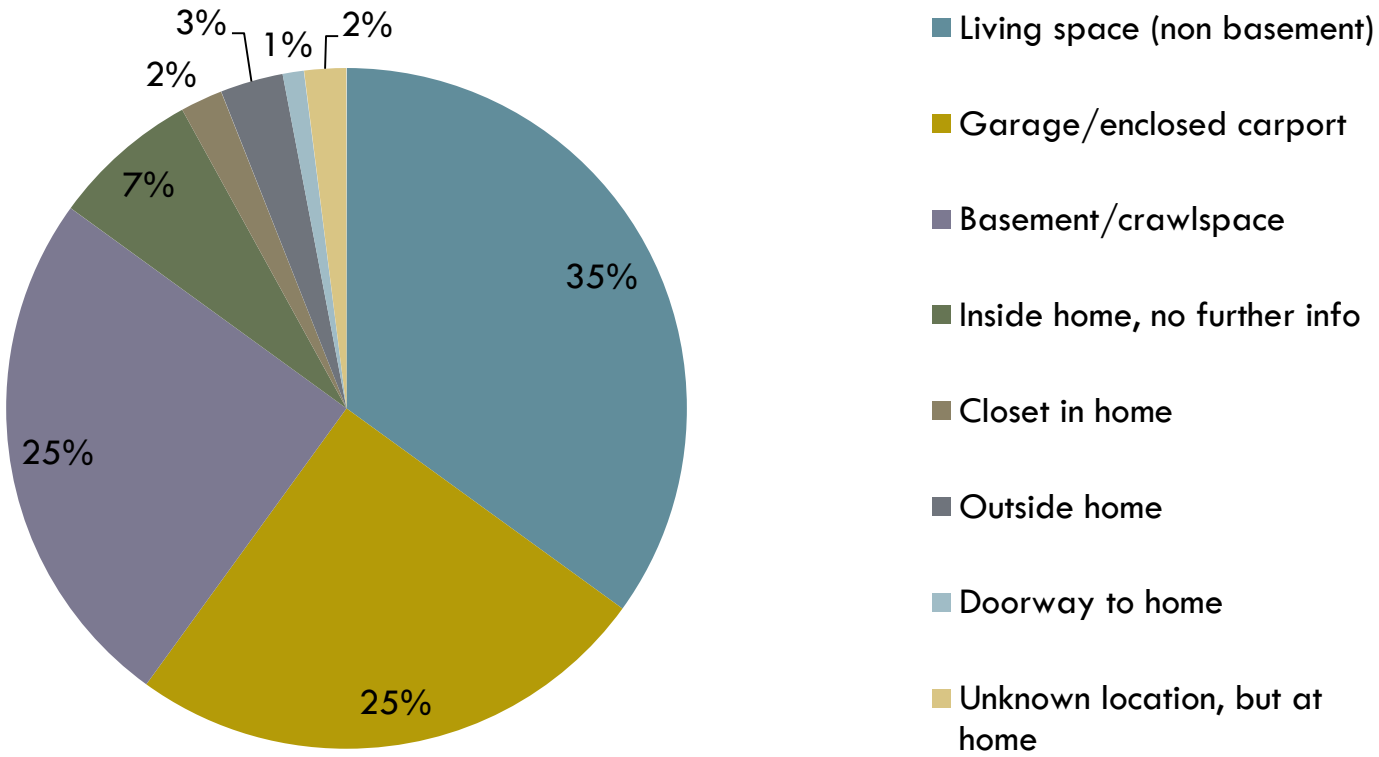
Fatalities Associated with Generators, by Location within Residence, 2004-2014



Source: U.S. Consumer Product Safety Commission, Directorate for Epidemiology, 2015

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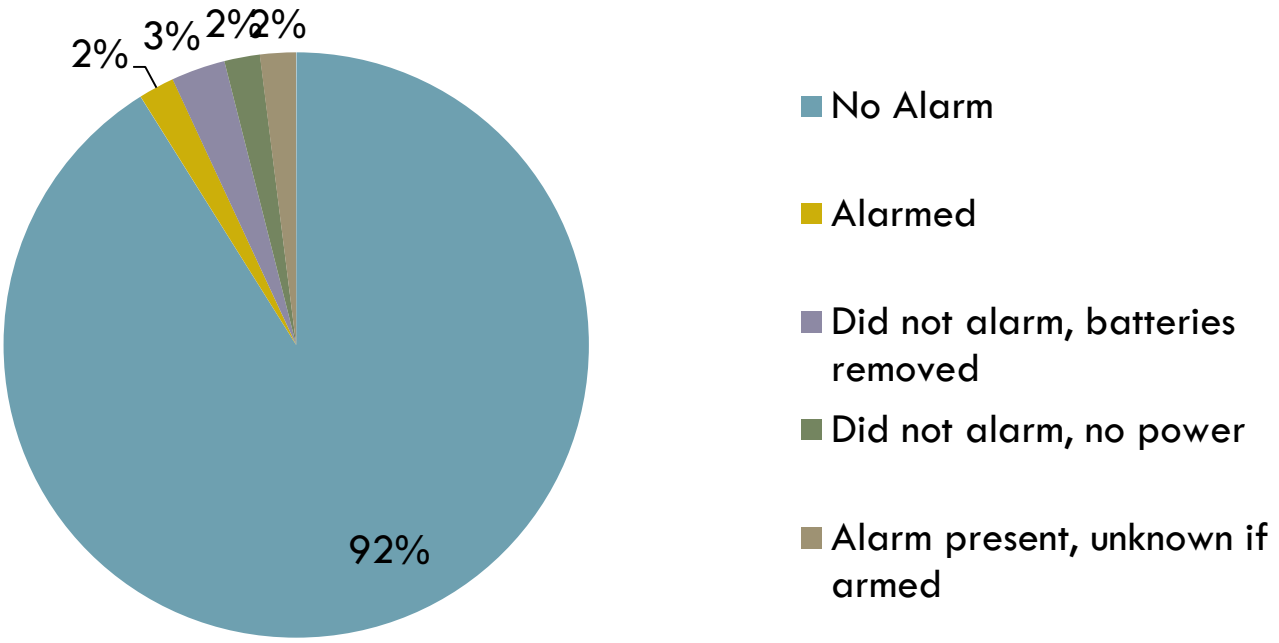
Fatalities Associated with Generators, - Carbon Monoxide Detector Present, 2004-2014



Source: U.S. Consumer Product Safety Commission, Directorate for Epidemiology, 2015

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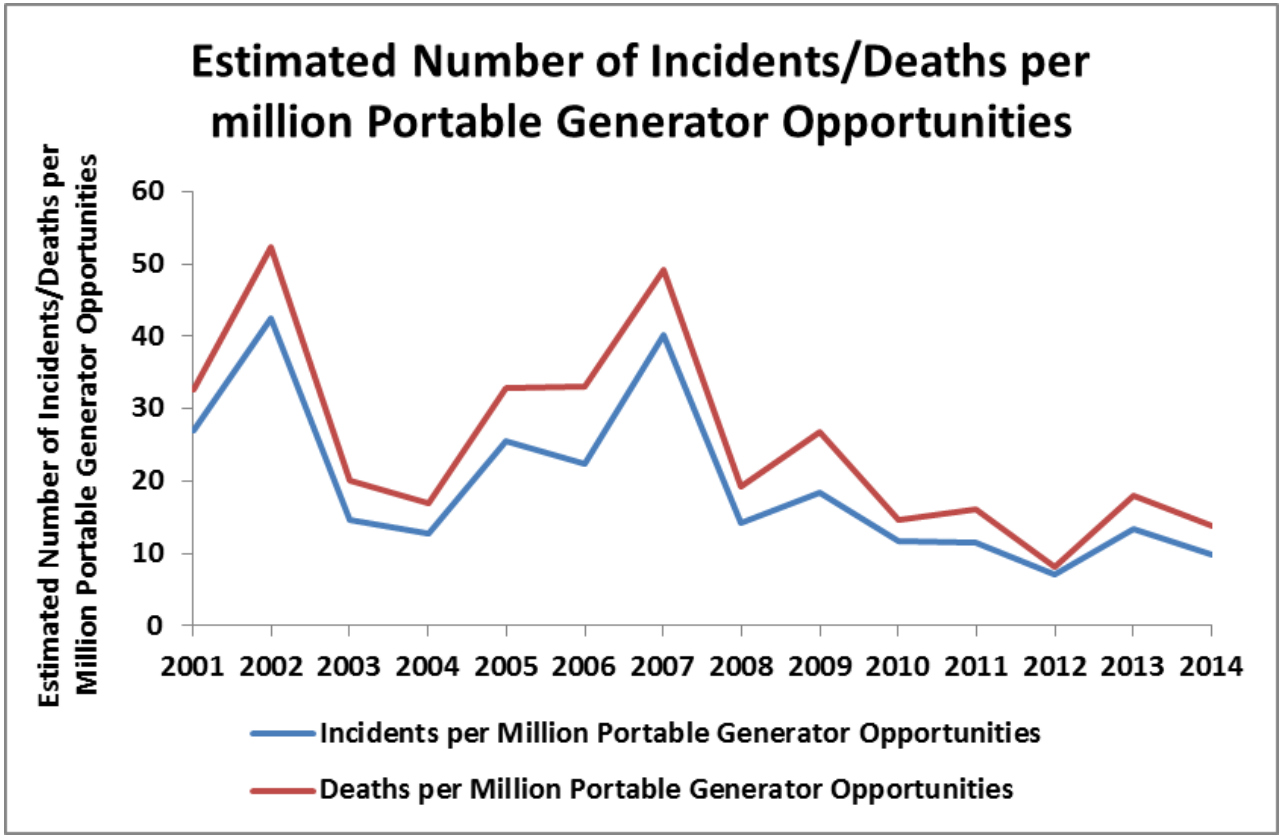
Background – Label and Safety Awareness Campaigns

Since the label requirement in 2007 and PGMA's public awareness safety campaign beginning in 2013, incidents have been decreasing.



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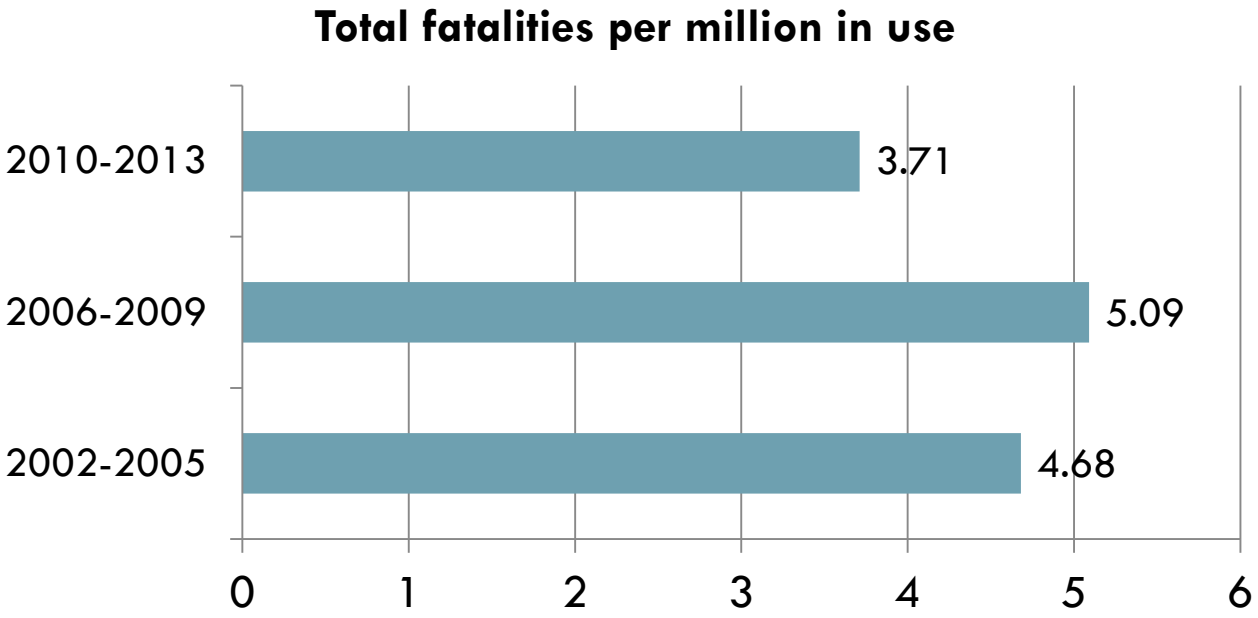
Additional view



The number of portable generators in use rose dramatically in each of these three-year periods, from an average of 13.6 million from 2002-2005 to 17.1 million from 2010-2013.

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PGMA Promotes the Safe Use of Portable Generators

- 2009 – Generator manufacturers join forces as PGMA to create and promote safety standards for portable generators and began work on safety standard.
- 2012 – Education Awareness Subcommittee Formed
- 2012 – Support adoption of CO monitor as part of building code
- 2013 – Support NARUC CA-1 Resolution Recognizing the Importance of Educating Consumers on Portable Generator Carbon Monoxide Safety
- 2013 – Communications Subcommittee Formed
- 2013 - Safety First Program Begins
- 2013 – PGMA contracts consultant to study deaths related to portable generators to identify trends that could be used to formulate potential solution options.
- 2014 – PGMA Public Relations Campaign Begins
- 2014 – PGMA actively participates and works collaboratively in the UL CO Task Group
- June 2015 - PGMA G300 *Safety and Performance of Portable Generators Standard* obtained recognition as an ANSI standard.
- October 2015 - PGMA Launches "Take it Outside™" Safety Awareness Campaign

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Safety First (2013)

- Campaign was developed to help raise awareness of CO dangers.
- Includes information on PGMA Website (pgmaonline.com), safety video, flyer and PSA.

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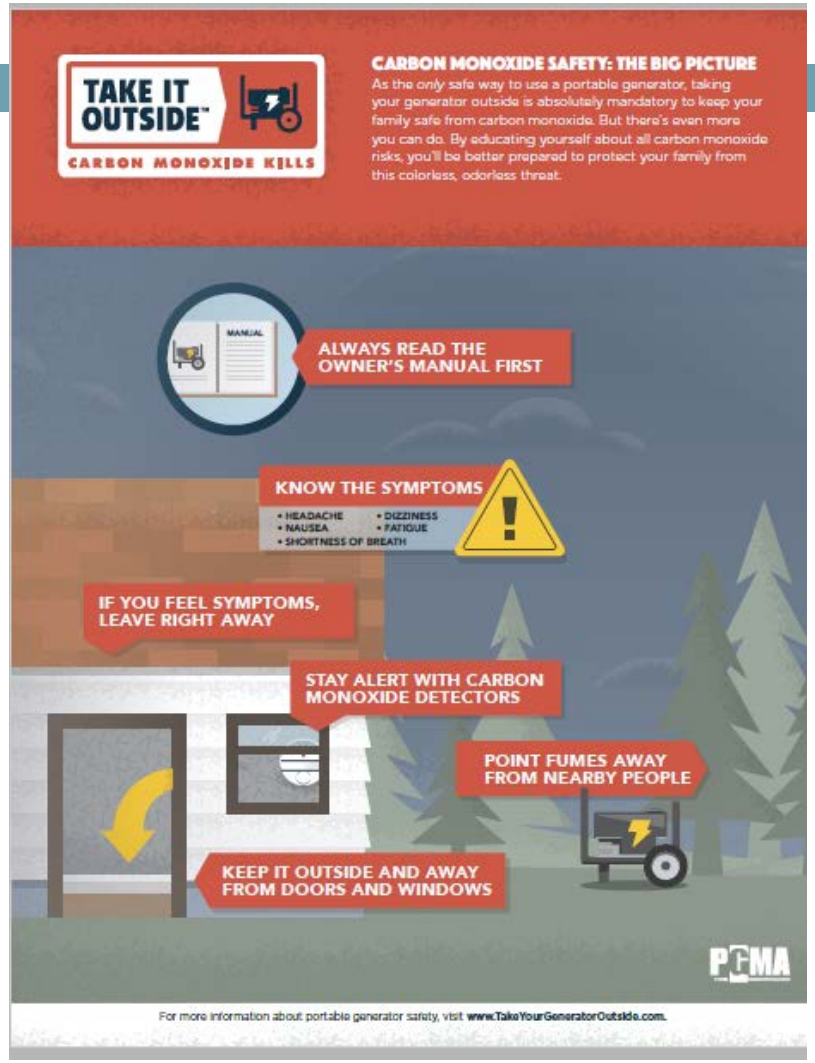
Safety Awareness Campaign

Goals:

- Increase the impact and reach of PGMA's carbon monoxide safety message to consumers.
- Position PGMA as the single reputable resource for portable generator safety issues and standards.
- Build awareness of preventative measures relating to carbon monoxide safety.



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Safety Awareness Campaign

Tactics:

- Campaign theme and logo
- Motion graphics video
- Website with landing pages for consumers and for manufacturers
- Social media messages
- Fact Sheet
- PSAs (video, radio, print)
- CO Safety Letter for utilities to use when shutting off power
- News Release

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PGMA's Steps for Promoting CO Safety Awareness

- Continuation of Public Relations campaign (started in 2014) which consists of monthly press or mat releases promoting safe use of generators during severe weather, power outages, and recreational activities that use portable generators. To date this has generated:
  - 20,691 media placements
  - Nearly 653 million impressions
  - There have been hits in 47 of the 50 states (excludes Montana, Utah and Wyoming).
- Expansion of "Take it Outside™" Safety Awareness Campaign
- ANSI / PGMA G300 Standard – Continuing to evaluate revisions for next edition including potential solutions for addressing CO Emissions.
- PGMA Tech Summit to help identify additional solutions.

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Technical Solutions – PGMA Brainstormed Ideas

- PGMA Technical Committee brainstormed potential technical solutions. Initial ideas included:
  - Add a CO alarm to the unit.
  - Provide a door that slides either over the ON/OFF switch or in front of the fuel valve with a LOGO that says to “Take it Outside”- The Consumer has to read, touch and physically move something to turn the generator on. It stays with the generator even after the manual and instructions have been long lost.
  - Add a CO shutdown system to the unit.
  - Add something to the catalyst to make the exhaust smell bad. Exhaust additives - bad smell, color. Add something to exhaust system to make it unpleasant to run indoors.
  - Add a timer to a CO detector shut down so that when life of detector is reached it disables the unit from starting until the detector is updated.
  - Add some form of user acknowledgement of CO Warnings before unit can be used each time. Impacts For example, a two-step starting process that requires acknowledgement that the gen is outdoors, i.e. navigation screens in vehicles
  - Add some form of environment monitoring to sense being inside a structure and prevent operation.

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Technical Challenges/Next Steps

Technical Challenges

- Potential unintended consequences of proposed UL solution - consumers continuing to use portable generators indoors.
- Industry wants to address issue but needed to better understand the misuse scenarios before continued development of potential solutions.
  - 2013 FOIA Request (data received December 2015) provided additional data to help identify root causes.

Opportunities/Next Steps

- Comparable product (stationary generator) on the market has specific requirements regarding use and placement (five feet away from home), demonstrating that with proper instructions, generators can be used safely.
- PGMA undertaking a study to better understand how effective the mandatory warning label is and how it could potentially be made stronger.

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Problem Solving:

Root Cause Brainstorming Session

March 17, 2016

Carbon Monoxide (CO) Fatality Incidents Associated with Portable Generators

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PGMA – February 19, 2016

- The following is a summary of the work completed in the Root Cause session held on 2/19/16, regarding CO incidents related to Portable Generators. Twenty-two members of the PGMA convened to create an affinity matrix of root cause issues which identifies behavioral conditions that may cause the use of CO producing equipment in an enclosed area.

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Purpose

- Identify behavioral root causes of a given event
- Create a Behavioral Matrix to identify the “lowest level” root

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The Behavioral Matrix

- The Behavioral Matrix identifies the characteristics of actions and behaviors that may cause the hazard to occur. These Root Cause factors may or may not appear on qualitative cause data.

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Our Process

Identify "Why run a generator in an enclosed area?"

5 why analysis to drill down into the situations

Multiple Root Cause identified

Compare and condense Situations

Rank Root Cause by characteristic

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Identifying Situations

- Participants were grouped into four teams
- Each team identified the SITUATION that would cause a person to run a generator in an enclosed area

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Cascade to Root Cause

- Analyze each situation to the lowest possible outcome.
- When you can't answer why any longer you have identified a final root cause.

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Multiple Situation – Single Root Cause

- Final Root Cause is verified against all Situations to identify root causes that occur in multiple events.

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Combine the Situational Events

- Situations identified in each team are next compared and condensed where applicable.

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Combine the Situational Events

- Root Cause identified are matched with the most probable Situation.

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Behavioral Matrix by Situation

SITUATION / CHARACTERISTIC	Noise		Weather							Theft			Lack of Planning			Power Out		Unaware of Danger							Convenience	
People	Illegal use	Embarrassed	Close to what you are working on	Don't want to get wet	Did not read manual due to lack of lights, electricity or due to urgency	Wrong oil	Human operation	Fear of electrical problem	Fear of shock				Insufficient plan	Manual not available											Physically cannot move	12
Education													Lack of preparation (no cord or, not length)	Not enough cords	Wrong cord			Didn't internalize risk	Under-educated and difficult to use	manual off site	Cannot detect the danger by smell	Borrowed unit (less accessibility and not as familiar)	No education	Rented without manual		10
Equipment	Lack of availability of quitter models		Ignition system design spark or speed	Not weatherproof	Potential damage	Electrical connections are not sealed				Portability			Functional features missing												Has to refuel often	8
Price	High cost of quitter models		Cost to weather proof is high	Cost comparative advantage	Cost erodes manufacturer margins																					4
Environment										Previous experience of theft	Heard from neighbors of theft	Frequent history of stolen goods														3
Event																Time constraint: needs to be quick	Storm related		manual is unnecessary - online instruction							3
Value										Expensive value to Lose	High Value Product															2
Technology																		Not necessary to read warning to operate	Labels not necessary to operate							2
Surroundings	Bothersome to others																									1
Policy			Weatherproof standards aren't optimize (conservative)																							1
Money																Out of money - Priority purchase										1
Skills																		Complacent - used for many years								1
Location																									Discomfort - avoid exposure to rain or get wet	1

The Behavioral Matrix identifies the characteristics of actions and behaviors that may cause the hazard to occur. These Root Cause factors may or may not appear on cause data. Eliminating or reducing these factors which are at the "lowest level" of Root Cause will facilitate the reduction or elimination of the Situation that led to the hazard.

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Behavioral Matrix by Characteristic

The Behavioral Matrix may also be sorted by Characteristics. By concentrating on the Characteristics multiple Situations may be eliminated or reduced.

CHARACTERISTIC												
People	Illegal use	Embarrassed	Close to what you are working on	Don't want to get wet	Did not read manual due to lack of lights, electricity or due to urgency	Wrong oil	Human operation	Fear of electrical problem	Fear of shock	Insufficient plan	Manual not available	Physically cannot move
Education	Borrowed unit (less responsibility and not as familiar)	cannot detect the danger by smell	Didn't internalize risk	Lack of preparation (no cord or not length)	manual off site	No education	Not enough cords	Rented without manual	und ereducated and difficult to use	Wrong cord		
Equipment	Electrical connections are not sealed	Functional features missing	Has to refuel often	Ignition system design spark or speed	Lack of availability of quitter models	Not weatherpro of	Portability	Potential damage				
Price	Cost comparative advantage	Cost erodes manufacturer margins	Cost to weather proof is high	High cost of quitter models								
Environment	Frequent history of stolen goods	Heard from neighbors of theft	Previous experience of theft									
Event	manual is unnecessary - online instruction (never read)	Storm related	Time constraint needs to be quick									
Value	Expensive value to Lose	High Value Product										
Technology	Labels not necessary to operate	Not necessary to read warning to operate										
Surroundings	Bothersome to others											
Policy	Weatherproof standards aren't optimize (conservative)											
Money	Out of money - Priority purchase											
Skills	Complacent - used for many years											
Location	Discomfort - avoid exposure to [illegible]											

Summary – Root Causes

- Noise
- Weather
- Education (Unaware of Danger, Lack of Planning)
- Power Out (Shut Off)
- Theft

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Next Steps

Use the Matrix to identify issues that can be solved by developing countermeasures to the Characteristics listed.

EDUCATION

Borrowed unit (less responsibility and not as familiar)	cannot detect the danger by smell	Didn't internalize risk	Lack of preparation (no cord or not length)	manual off site	No education	Not enough cords	Rented without manual	under-educated and difficult to use	Wrong cord

"By using the category above what can be done to eliminate or reduce the occurrence?"

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Summary

Identified “lowest level” Root Cause by sorting through Situational events.

Categorized Root Causes into Characteristics

Created the Behavioral Matrix to better identify Root Causes to address in order to eliminate or reduce hazards.

CPSC Staff Technical Research to Address the Carbon Monoxide Hazard for Portable Generators

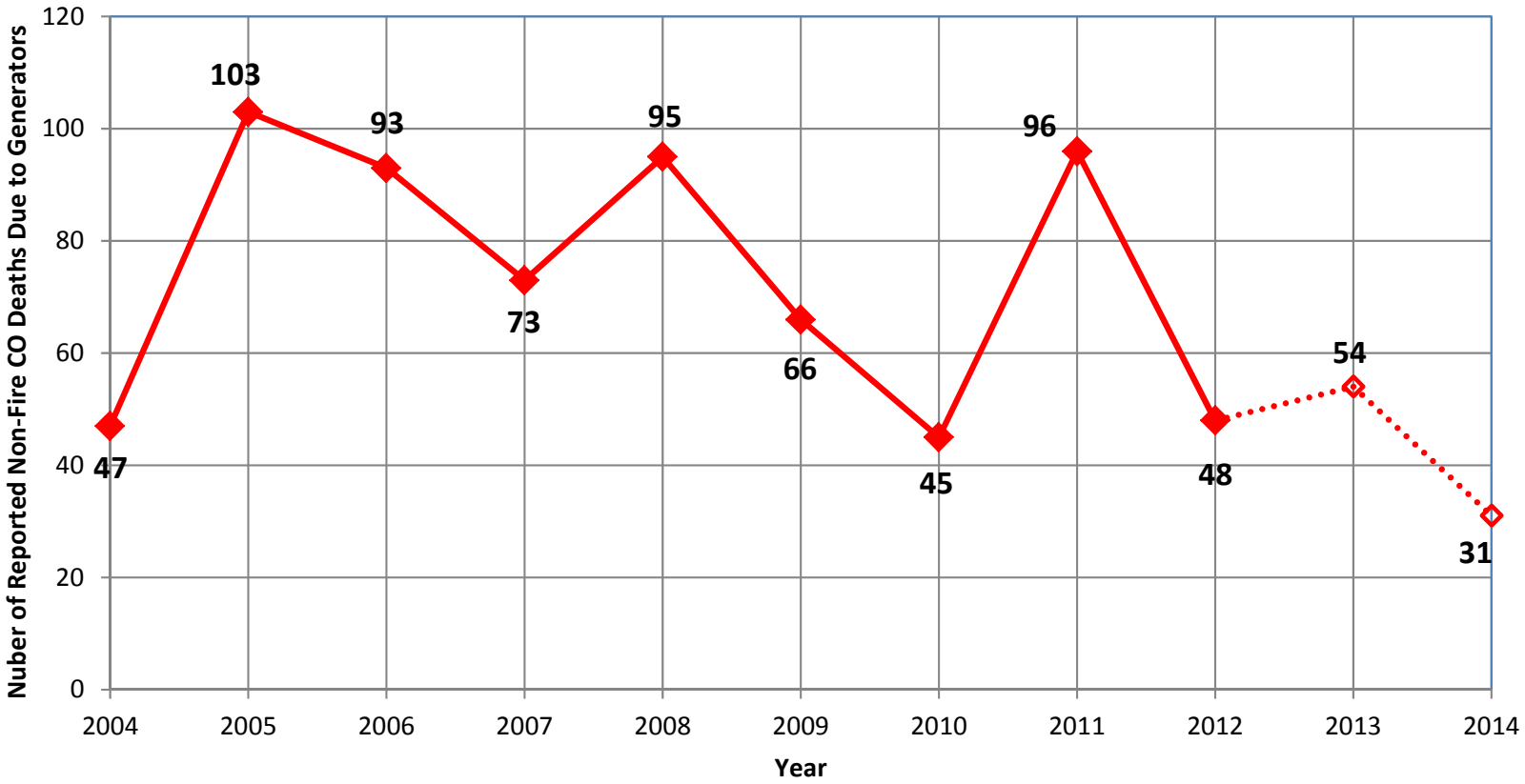
PGMA Technology Summit
March 17, 2016

The material contained in this presentation is that of the CPSC staff and has not been reviewed or approved by, and may not necessarily reflect the views of, the Commission.

U.S. Consumer Product Safety Commission

Why CPSC Is Concerned About Generators

Number of Reported CO Deaths Associated with Portable Generators



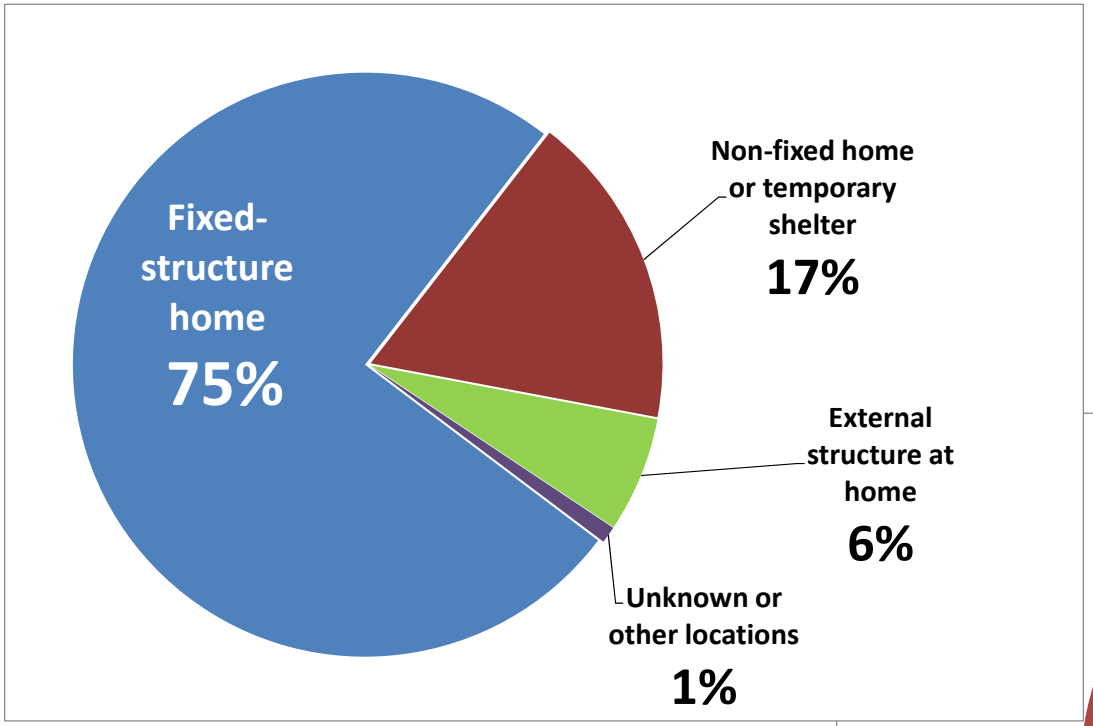
Reporting for years 2013 and 2014 is considered incomplete and is likely to change in future reports.

Reporting for years 2004-2012 is considered largely complete but may change to a relatively small extent in future reports.

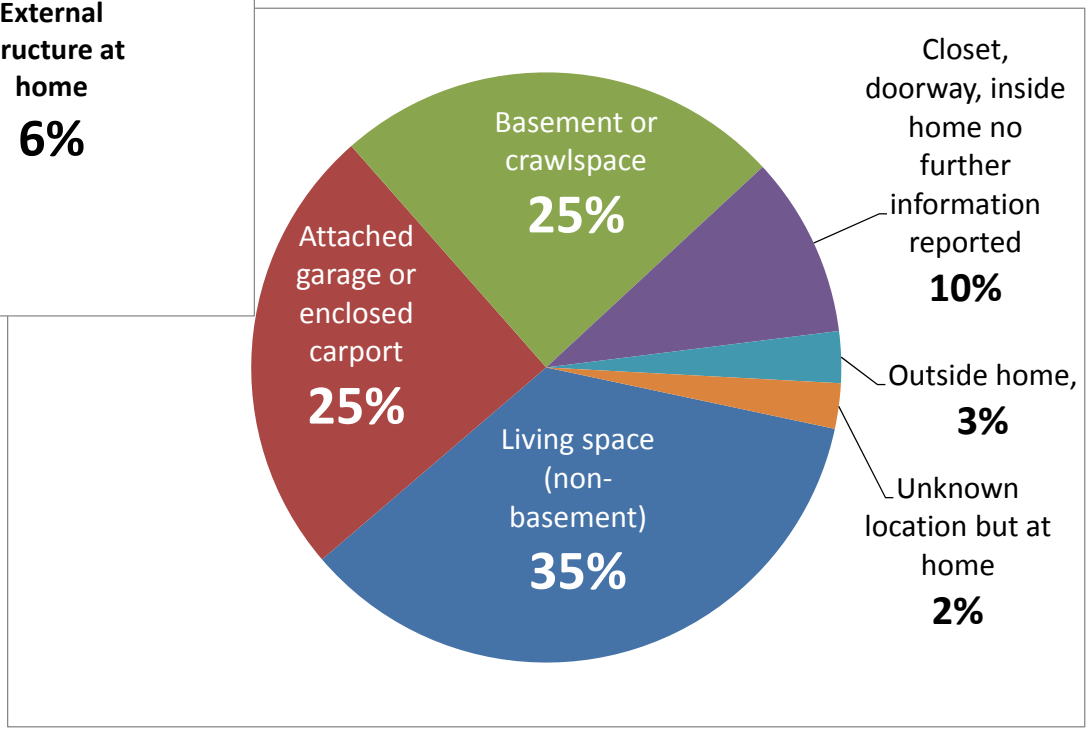
Source: Hnatov, M. V. *Incidents, Deaths, and In-Depth Investigations Associated with Non-Fire Carbon Monoxide from Engine-Driven Generators and Other Engine-Driven Tools, 2004-2014.* U.S. Consumer Product Safety Commission, June 2015.

Some of our hazard analysis…

Location where incident occurred



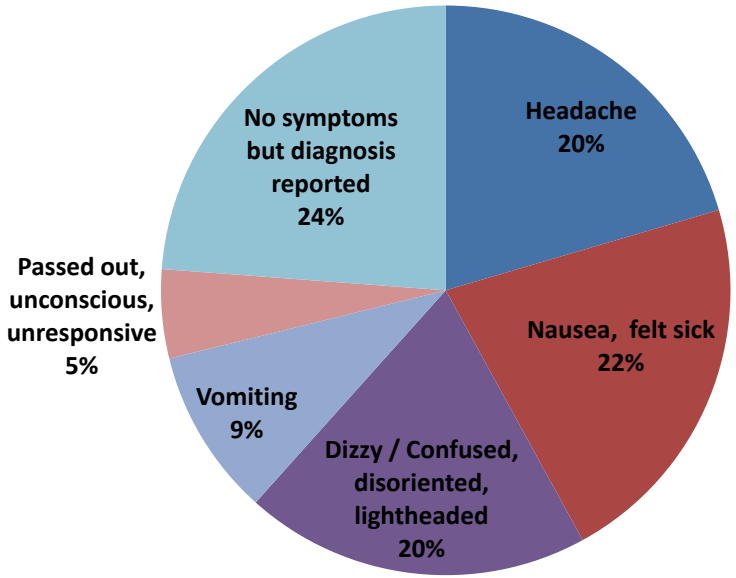
Specific location of generator in incidents that occurred in fixed-structure home location



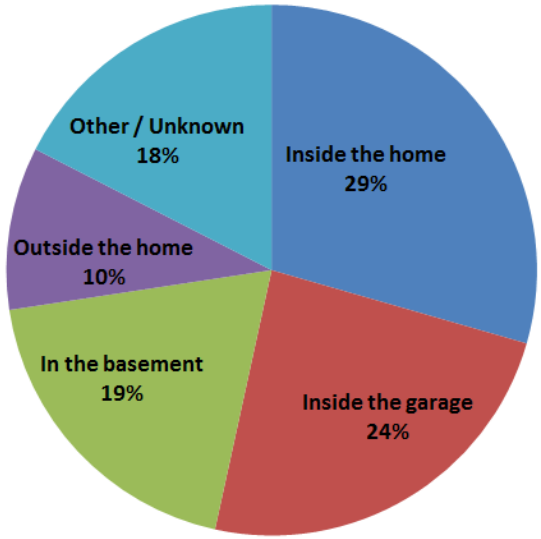
CO Injury Estimates

8,703 estimated generator-related CO injuries seen in ERs in 2004 through 2012[1]

Most Common Symptoms Reported in NEISS CO Cases Associated with Generators, 2004-2014[2]



Location of Generator Reported in NEISS CO Cases Associated with Generators, 2004-2014[2]



Sources:

1. Hanway, Stephen, *Injuries Associated with Generators Seen in Emergency Departments with Narratives Indicative of CO Poisoning 2004-2012 for Injury Cost Modeling,* U.S. Consumer Product Safety Commission, Bethesda, MD, March 2016
2. Hnatov, Matthew, *Summary of NEISS Records Associated with Carbon Monoxide Exposure Cases Related to Engine-Driven Generators in 2004 through 2014,* U.S. Consumer Product Safety Commission, Bethesda, MD, March 2016

Small Engine CO Emission Rates Compared to Cars

5kW generator

=

280 – 625 cars

Typical engine powering a 5 kW generator emits a weighted average CO rate of nominally 1500 g/hr(1)

Idling mid-size late 1990's-vintage cars emit 2.4 – 5.4 g/hr (2) of CO

Sources:

1. http://www3.epa.gov/otaq/certdata.htm#smallsi
2. Frey, H., et al., *On-Road Measurement of Vehicle Tailpipe Emissions Using a Portable Instrument*, Journal of the Air & Waste Management Association, Vol.53, August 2003.

Distributed by Joel Recht, CPSC staff at PGMA Public Meeting 9/17/2016

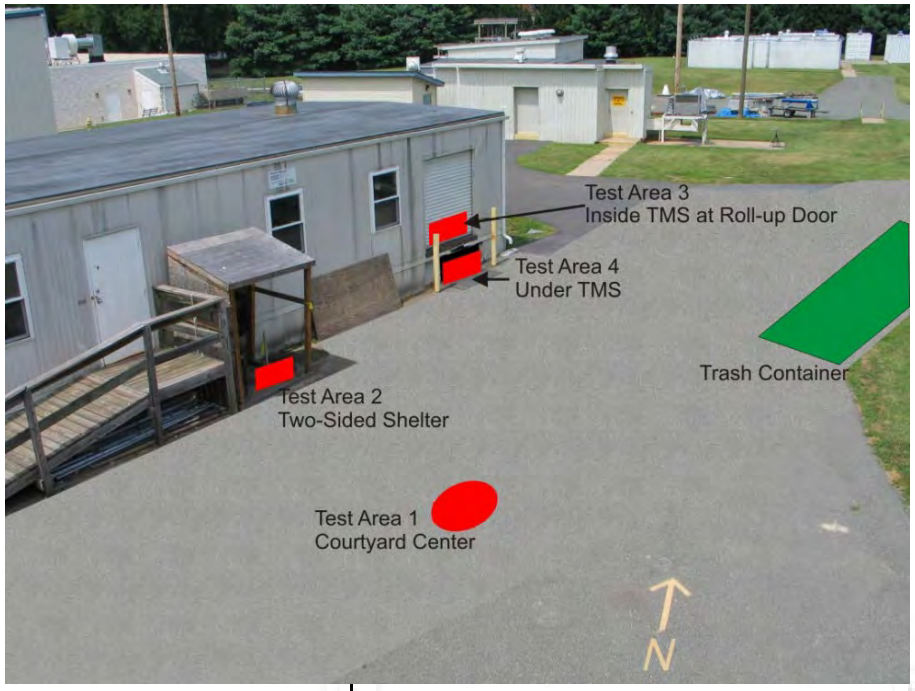
Overview of CPSC Efforts to Address the CO Hazard

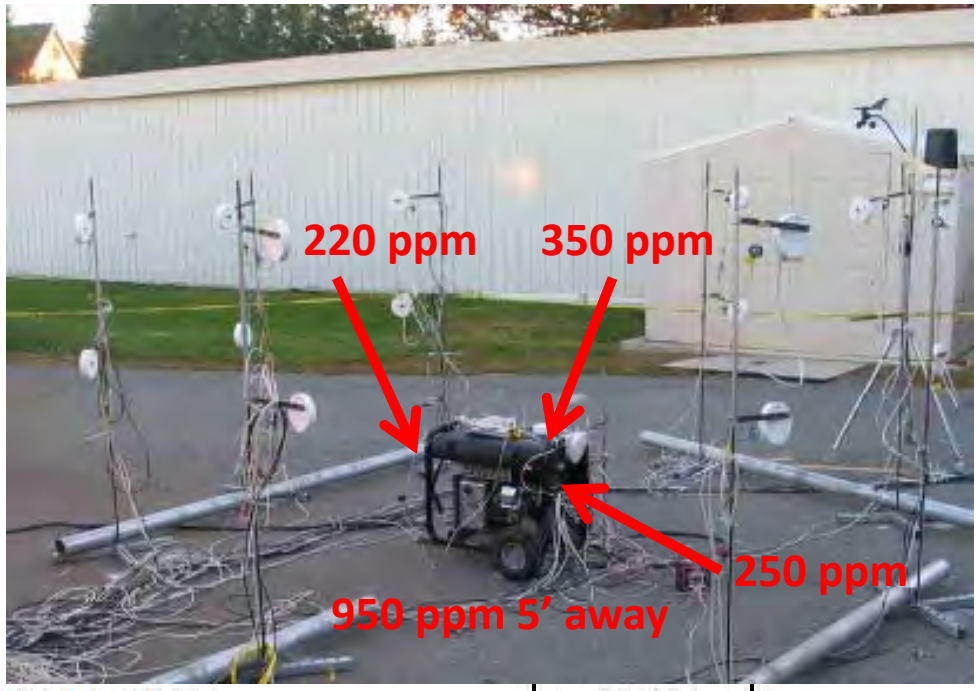
- STP for UL 2201 since inception – 2002 to present
- Public Forum - 2004
- Staff Report "Review of Portable Generator Safety" – 2006
- Advanced Notice of Proposed Rulemaking - 2006
- Mandatory Label – 2007
- Shutoff concepts - 2006 to present
- CO emission rate reduction – 2006 to present
- CO Task Group for UL 2201 – 2014 to present
- Canvass committee for ANSI/PGMA G300 - 2015

Shutoff Concepts Investigated by CPSC Staff

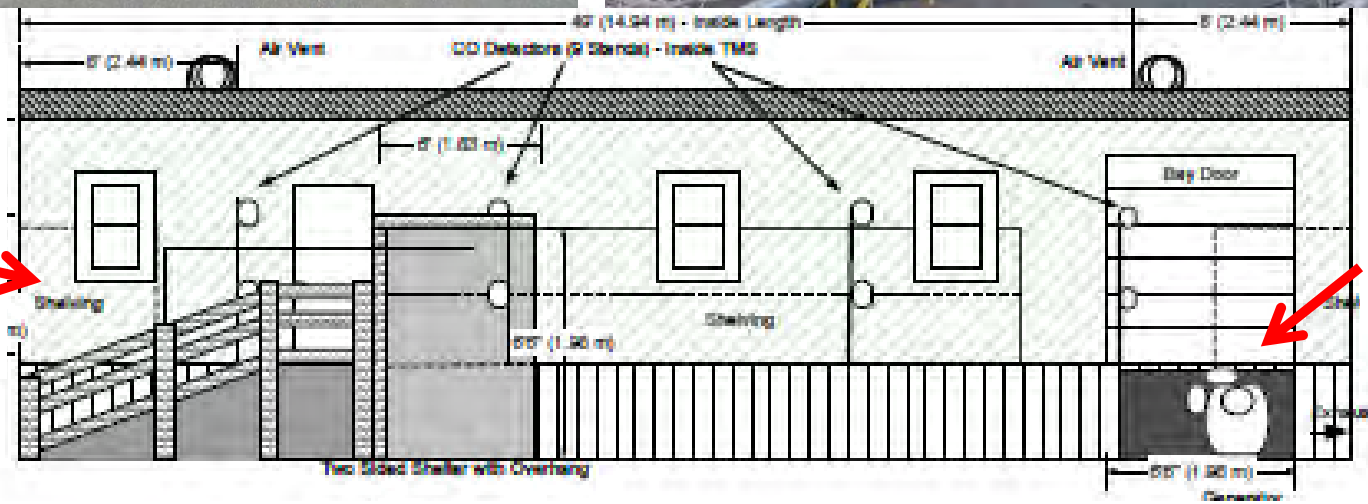
- Staff focusing on designing out the risk of CO poisoning from portable generators through any number of technologies.
- CO sensing system mounted on generator
- Remotely located CO sensing system that communicates with generator; relies on user to place sensing unit in proper location
- GPS system mounted on generator; relies on poor signal strength to infer generator is located indoors
- Algorithm programmed into engine control unit (ECU) on prototype; relies on electronic fuel injection (EFI) system sensors to infer indoor operation

Generator-Mounted CO Sensing System





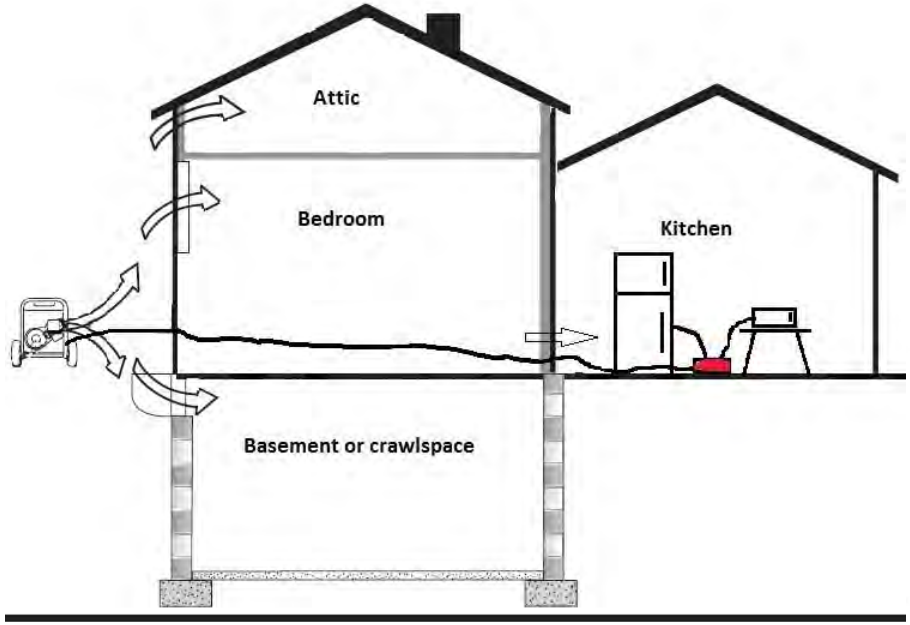
1000 ppm measured in this end of building before CO sensors mounted on generator shut it off

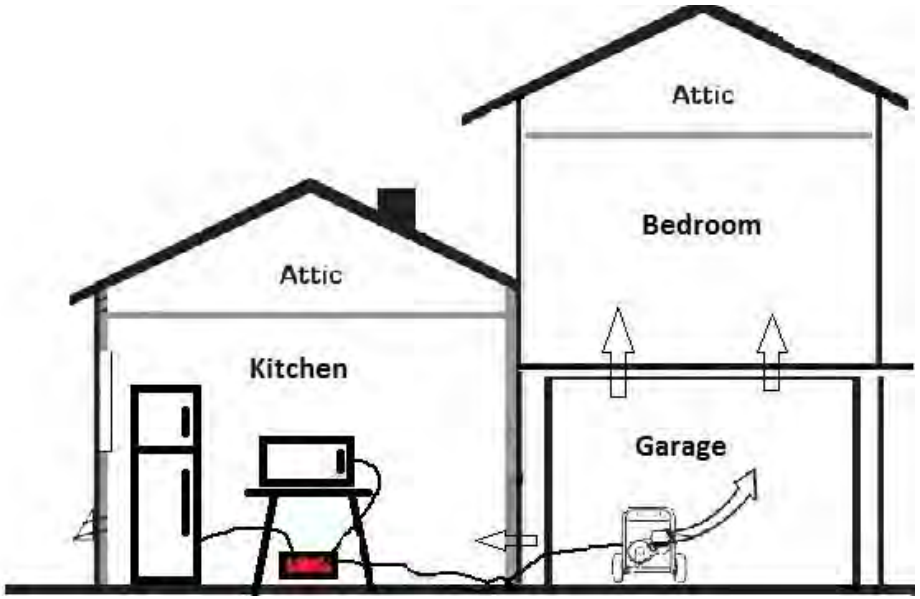


Generator operated inside - bay door closed

Source: Brown, Christopher, *Engine-Driven Tools, Phase 2 Test Report: Portable Generator Equipped with a Safety Shutoff Device*, U.S. Consumer Product Safety Commission, Bethesda, MD, July 2008.

Remotely Located CO Sensors for Generator Shutoff System: Pitfalls of Relying on User to Find Best Location for CO Sensor

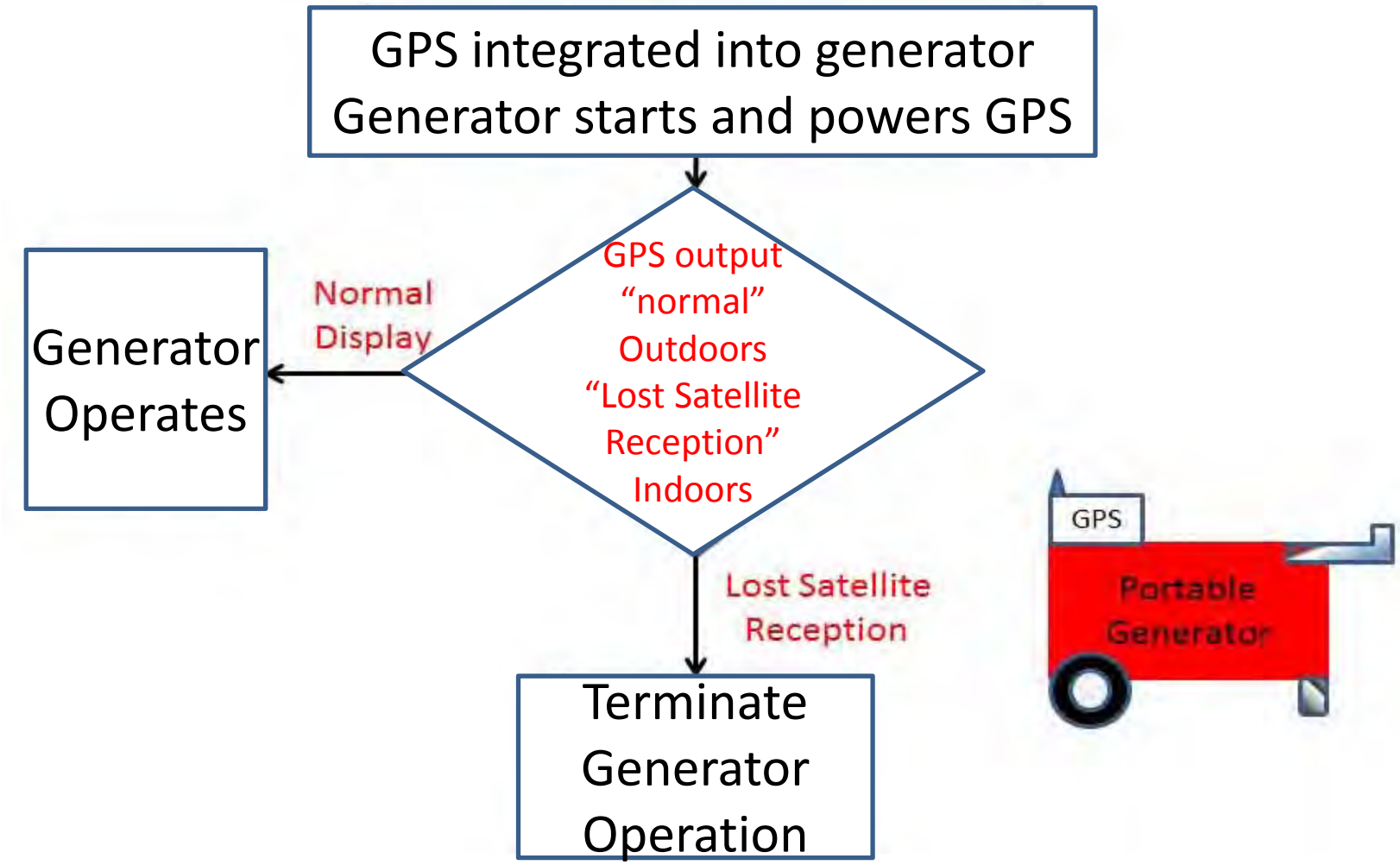




- Generator outdoors
- CO infiltrates rooms without sensor
- Danger in those rooms

- Generator in garage
- CO infiltrates rooms without sensor
- Danger in those rooms
- Consumer entering garage will walk into potentially lethal environment

Generator-Mounted Global Positioning System to Infer Generator Is Located Indoors



Source: Lim, Han, *Investigating the Utility of Global Positioning System (GPS) Technology to Mitigate the Carbon Monoxide (CO) Hazard Associated with Portable Generators – Proof of Concept Demonstration*, U.S. Consumer Product Safety Commission, Bethesda, MD, June 2013.

Generator-Mounted Global Positioning System to Infer Generator Is Located Indoors

Home	Indoor Detection	Front Yard (Outdoor) Detection	Back Yard (Outdoor) Detection
Single -family detached home with 2-car garage	YES	YES	YES
Townhouse with 1-car garage	YES	YES	YES
Single-family detached home with 4-car garage	YES	**NO**	YES
Single-family detached home with 1-car garage	YES	YES	YES
Single-family, one level detached home with detached garage (2-car garage)	YES	YES	YES
Single-family detached home with 1-car garage	YES	YES	**NO**
Single-family, detached one-level home, no garage	YES	**NO**	**NO**

Distributed by Joel Recht, CPSC staff at PGMA Public Meeting 9/17/2016

Algorithm Programmed into Prototype Generator's Engine Control Unit (ECU) (University of Alabama)

- UA developed algorithm to sense when generator is operating in an enclosed space and automatically shut it off
  - No additional sensors beyond those already integral to the existing engine management system
  - First algorithm: testing by CPSC staff and NIST found unacceptable
    - occasionally shut the generator off when operated outdoors
    - under certain circumstances would not shut off when operated indoors
  - Second algorithm: limited testing performed by UA
    - shut off when operated indoors (7 tests)
    - did not shut off when operated outdoors (5 tests)

Source: Haskew, Timothy, PhD., Paul Puzinauskas, *Advanced Algorithm Development and Implementation of Enclosed Operation Detection and Shutoff for Portable Gasoline-Powered Generators*, University of Alabama, October 2013.

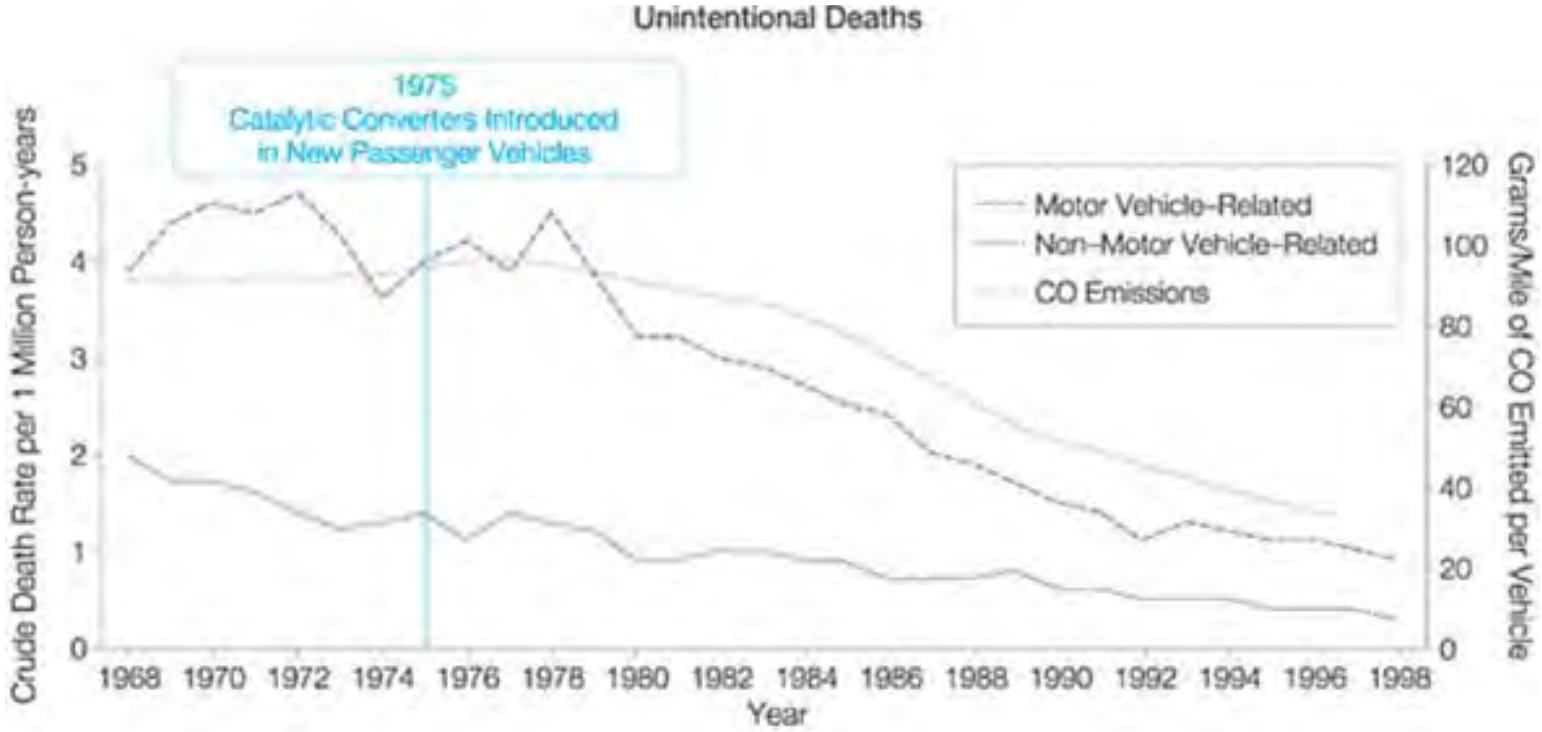
Safety-Critical Requirements for Systems Intending to Prevent CO Deaths and Injuries When Generator is Used Indoors

If intent with shutoff strategy is to prevent CO injuries and deaths when generator is operated indoors, then:

- shutoff must occur before exhaust creates unsafe CO exposure
- In addition, consideration needs to be given to requirements for:
  - a supervisory circuit that prevents the generator from starting if shutoff system:
    - is bypassed due to consumer tampering, or
    - fails in some way (contaminated sensor, discharged battery, etc.)
  - durability so that the system will work throughout the generator's operational life without the need for calibration or service

CO Emission Rate Reduction Strategy to Reduce CO Deaths and Injuries

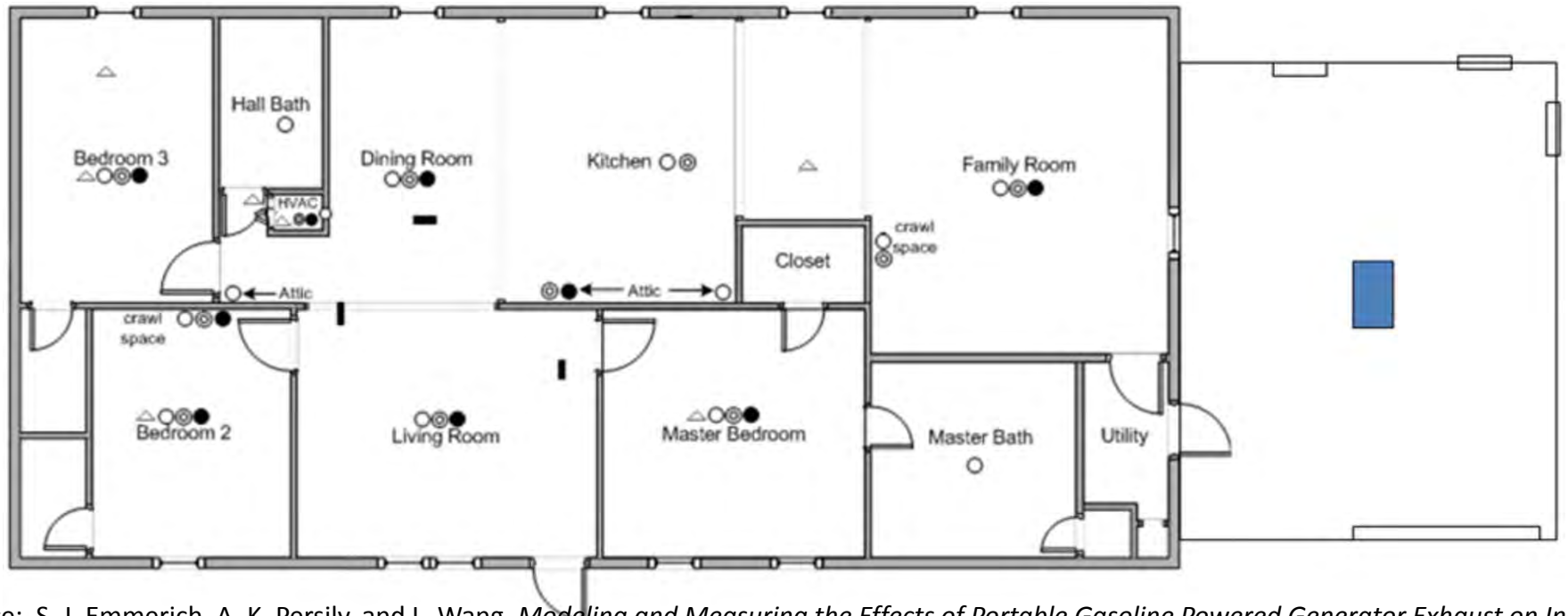
- 5.0 g/kW-hr CO emission standard specifically for small SI engines powering marine generators. Limit for all other small SI engines is 610 g/kW-hr.
- 4.4 g/kW-hr CO emission standard for large SI engines powering equipment designed for use in enclosed spaces.



Source: Mott, J.A., et al., *National Vehicle Emissions Policies and Practices and Declining US Carbon Monoxide-Related Mortality*, Journal of the American Medical Association, 288 (8): 988-995, August 2002.

Hazard Characterization of Common Incident Scenario: Generator operation in SFH attached garage

National Institute of Standards and Technology (NIST)

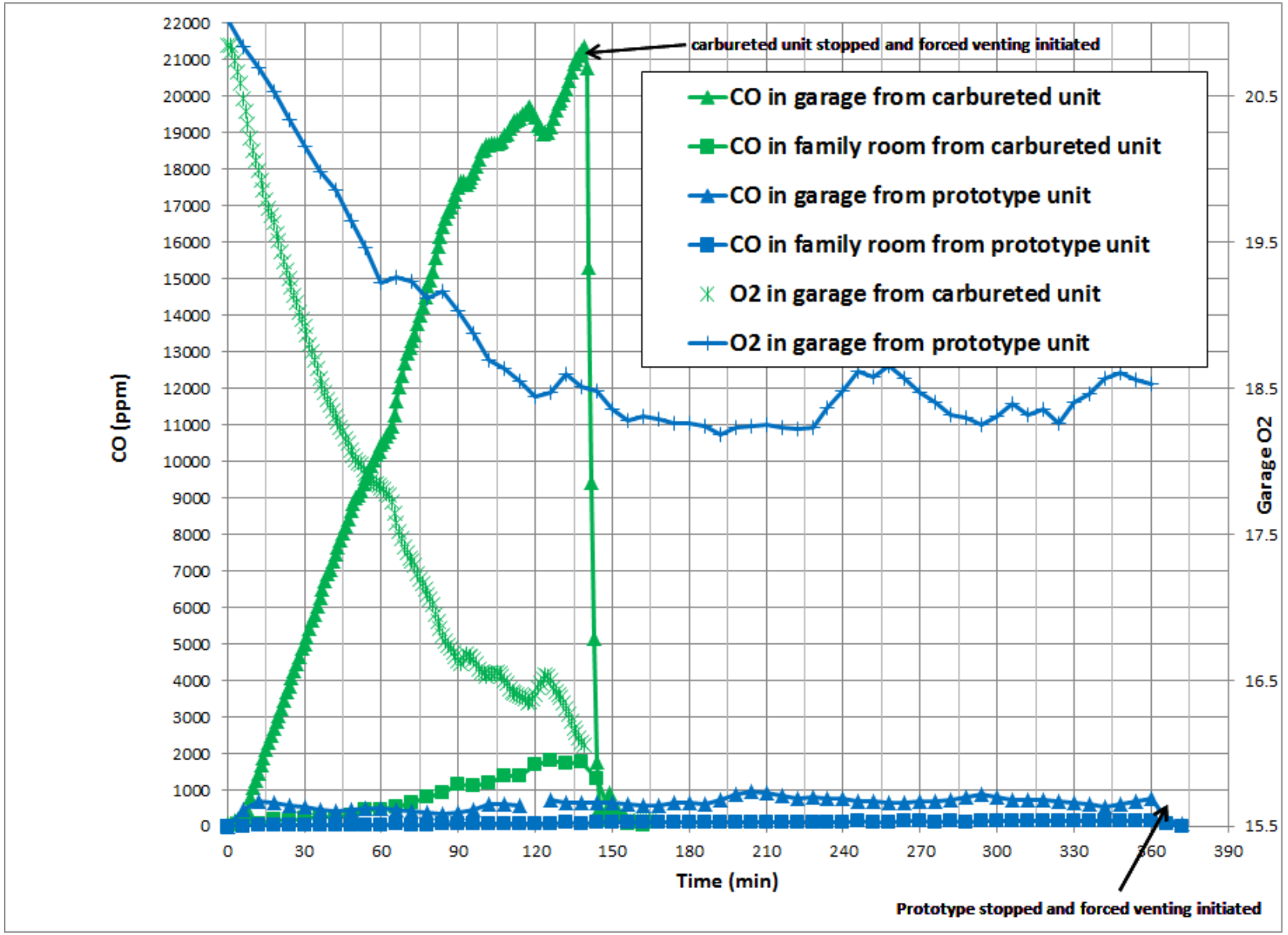


Source: S. J. Emmerich, A. K. Persily, and L. Wang, *Modeling and Measuring the Effects of Portable Gasoline Powered Generator Exhaust on Indoor Carbon Monoxide Level* (NIST Technical Note 1781), Feb 2013.

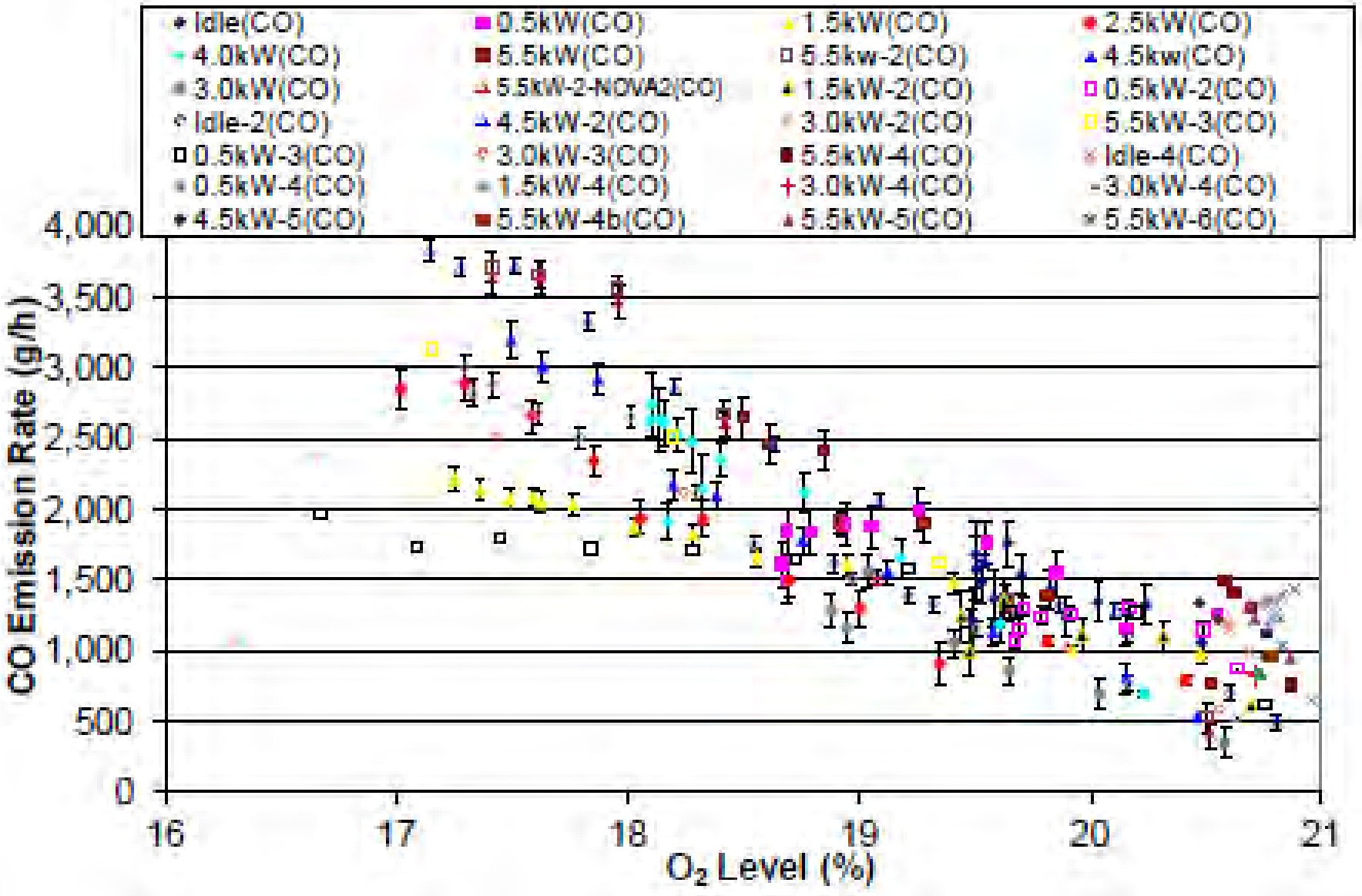
Garage and Family Room CO Concentration Profiles from Unmodified, Carbureted 5 kW Unit and Prototype 5 kW Unit

6-load hourly load profile applied to generator

Garage Bay Door Fully Closed, Garage/Utility Room Door Fully Closed, and HVAC Fan On



NIST's Determination of Generators' CO Emission Rates at Reduced O_2



UL CO Task Group

- **Staff committed to actively engaging in all voluntary standards efforts to address CO poisoning from portable generators**
- **CO emission reduction strategy**
  - Performance requirement that sets a limit on the generator's CO emission rate
  - Test method for CO emission rate when the O_2 in the intake air is below ambient (20.9%)
    - Subgroup for test method is developing alternative options to NIST's test method
- **Shutoff strategy**
  - If intent with shutoff strategy is to prevent CO injuries and deaths when generator is operated indoors, then
    - Shutoff must occur before exhaust creates unsafe CO exposure
    - In addition, consideration needs to be given to requirements for:
      - Supervisory circuit that prevents the generator from starting if shutoff system:
        - is bypassed due to consumer tampering, or
        - fails in some way (contaminated sensor, discharged battery, etc.)
      - Durability so that the system will work throughout the generator's operational life without the need for calibration or service
  - To also address CO deaths and injuries when generator operated outdoors and exhaust infiltrates indoors, limit on CO emission rate in ambient oxygen needed as well

CO and Boating: The NIOSH Experience

CAPT Ronald M. Hall, MS, CIH. CSP

Disclaimer: The findings and conclusions in this presentation have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy

Disclaimer: Mention of any company or product does not constitute endorsement by CDC, NIOSH

Initial Involvement—Lake Powell 2000-2001

- After the August 2000 death of two young brothers swimming near their houseboat, the DOI and NPS requested assistance from the NIOSH to evaluate potential boat-related exposures to CO on Lake Powell

- An initial review of EMS dispatch records as well as law enforcement and hospital records identified 137 CO poisoning cases between 1990-2001 on Lake Powell
  - 91 were on houseboats with 43 poisonings occurring outdoors

- From 1990-2008, 767 total CO-related poisonings on boats have been identified across the U.S.
  - Over 300 poisonings from generator exhaust

Source: National Case Listing, 2009
http://www.doubleangel.org/documents/NatlCaseListingBoat-RelatedCOPoisoningsMay2007April2008_000.pdf

Relative CO Concentrations

CO in ppm	Limits/Symptoms
35	NIOSH REL; Max. exposure allowed by EPA outside for 1 hour
50	Maximum exposure allowed by OSHA over 8 hours
125	American Boat & Yacht Council limit over 5 minutes
200	NIOSH Ceiling; Mild headache, fatigue, nausea & dizziness
800	Dizziness, nausea, convulsions - 45 min, Death - 2 hours
1,200	Immediately Dangerous to Life and Health (IDLH)
6,400	Death in 10 to 15 min
5,000 - 10,000	Measured in open air or near swim platform
12,000	Immediate Death
7,000 - 30,000	Measured on houseboats in airspace under swim platform
	Source: NIOSH, AIHA and ABYC

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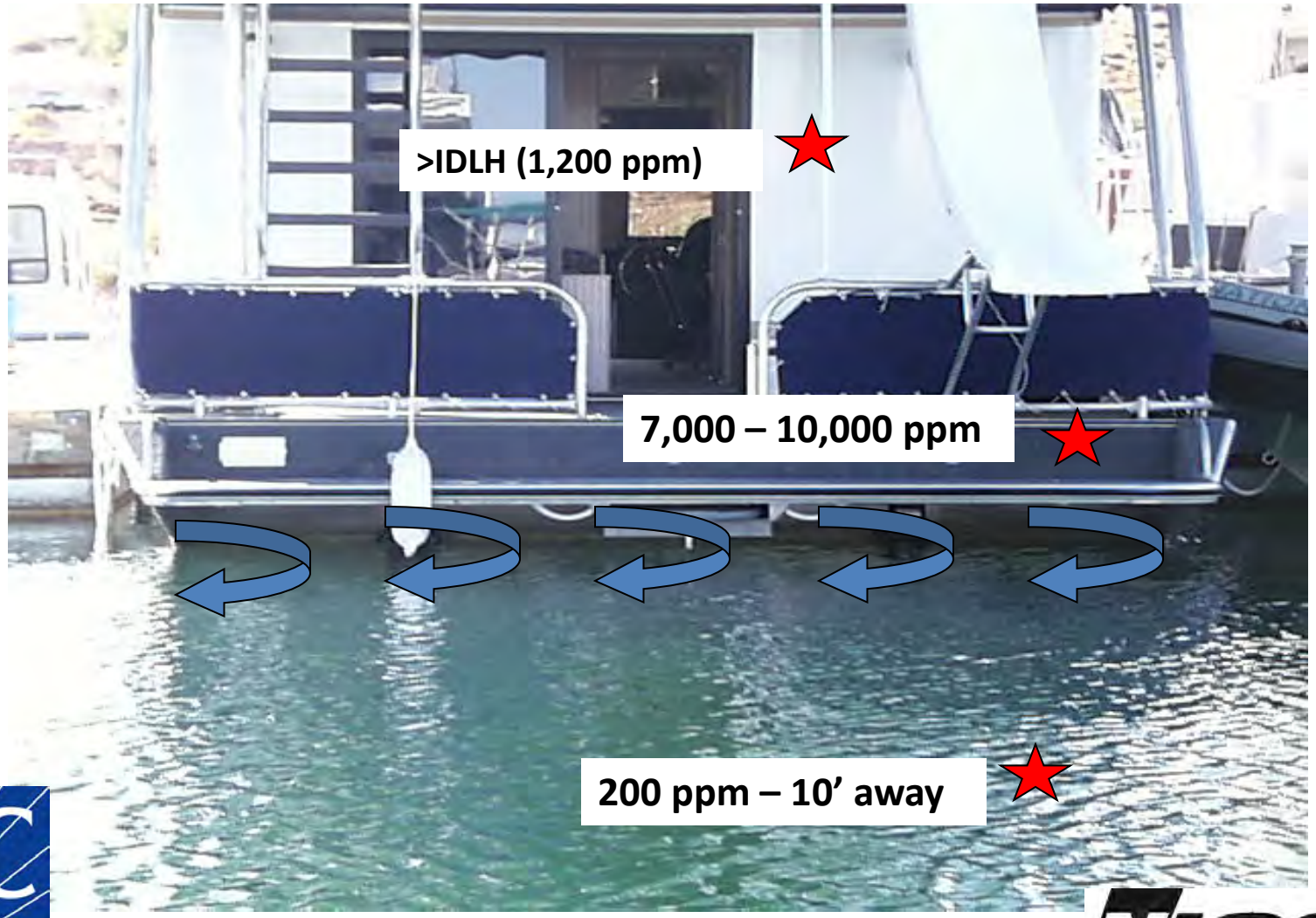
CO Concentrations – Generator Only Operating



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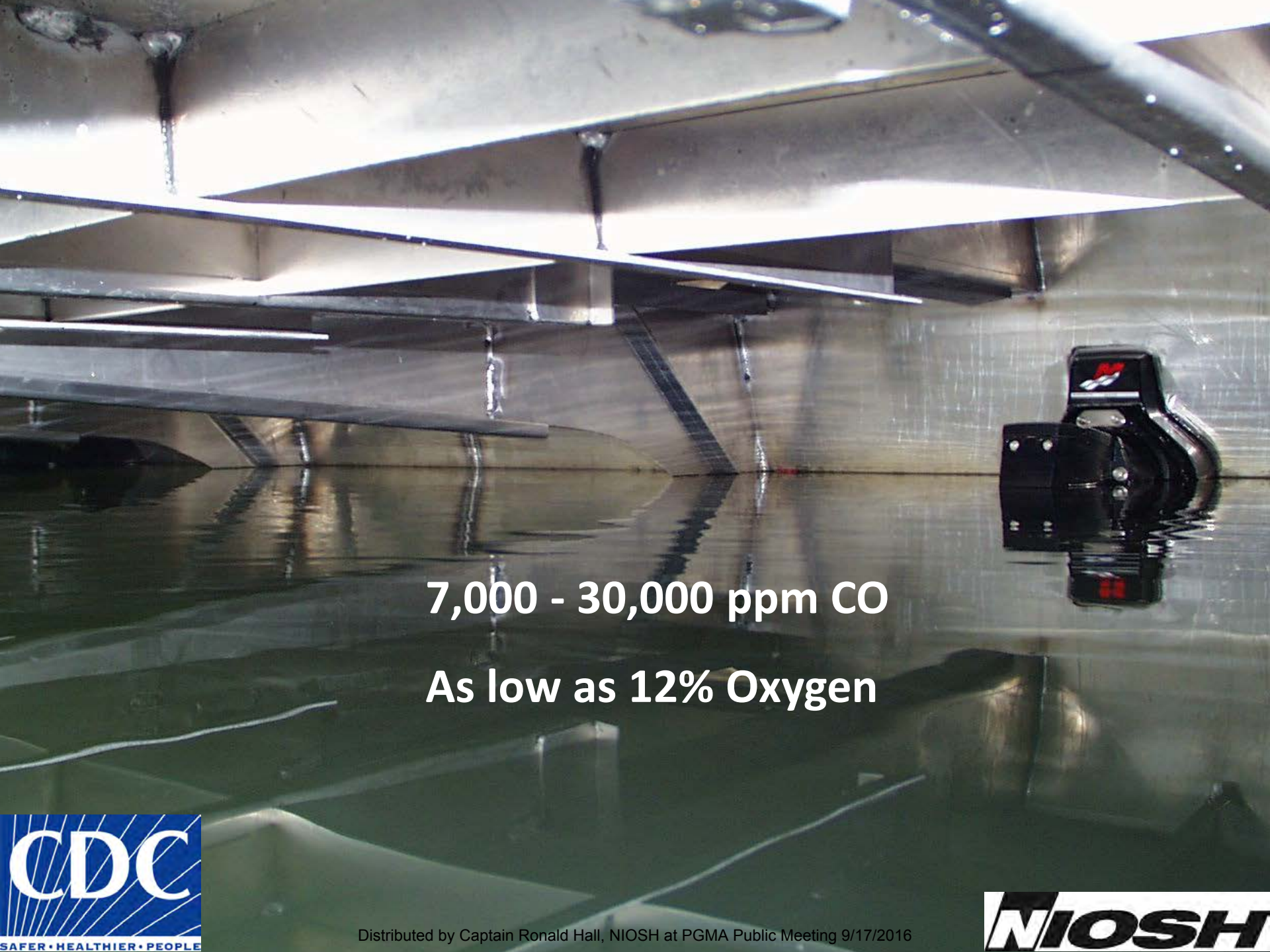

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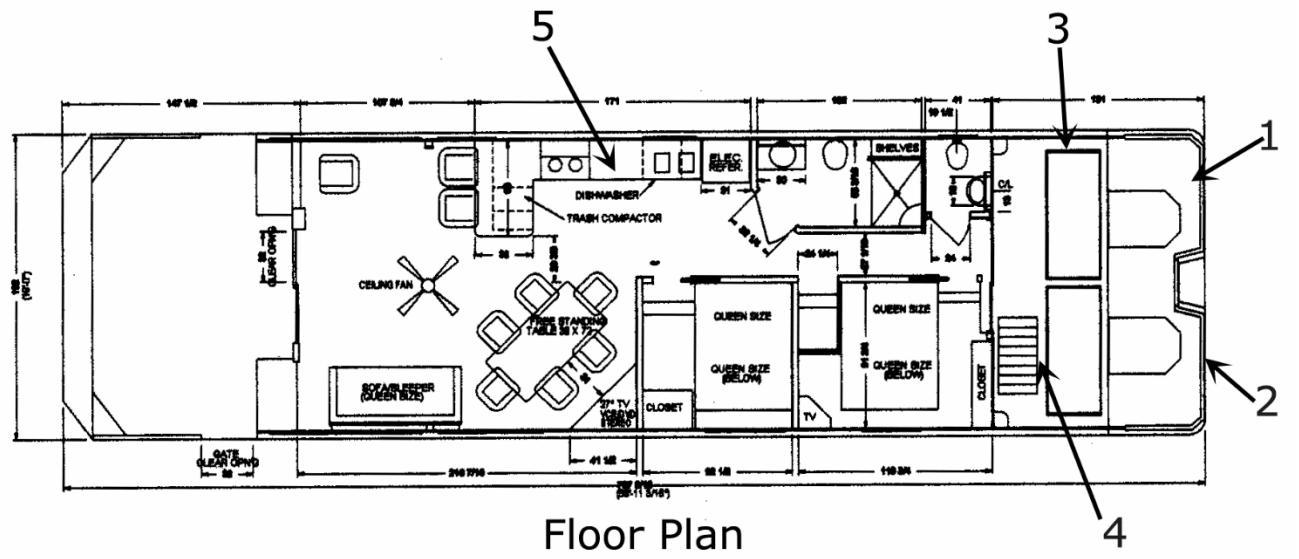
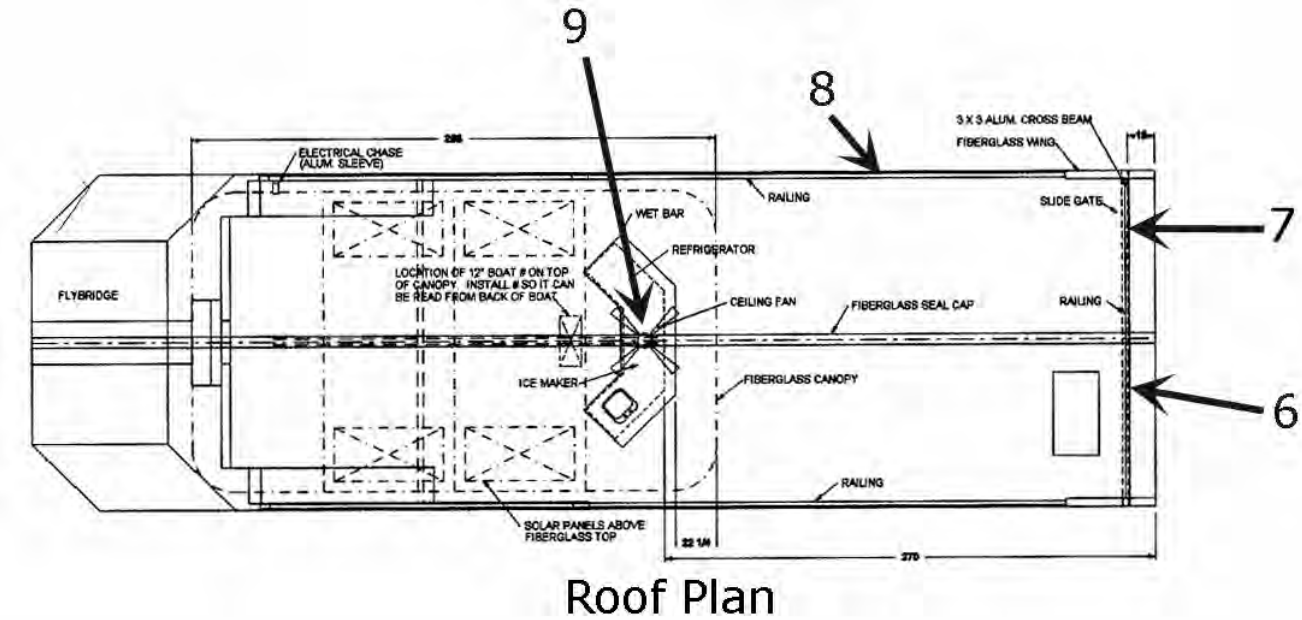
Sampling Locations of CO Monitors



Floor Plan



Roof Plan

Distributed by Captain Ronald Hall, NIOSH at PGMA Public Meeting 9/17/2016

NIOSH EFFORTS & NATIONAL WORKSHOP LED TO ENGINEERING CONTROL DEVELOPMENT

CO-Related Poisonings and Gen Development

- Prototype emissions control device (catalytic converter) was introduced into the market in 2001
- Generator manufacturers developed Low CO emissions generators
  - Westerbeke Safe-CO marine generators in 2004
  - Kohler launched low CO generators in 2005
- Evaluations of the both the Westerbeke and Kohler generators showed reductions in CO emissions by 99% or greater

Low CO Emission Gen Sets

Reduce Carbon Monoxide Emissions more than 99%

- **Westerbeke Low-CO Generator**
  - 3.5 kW to 22.5-kW generators available

- **Kohler Generator**
  - 4kW to 15 kW generators available

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HOUSEBOATS WITH GENERATOR DRY STACK RAFTED TOGETHER

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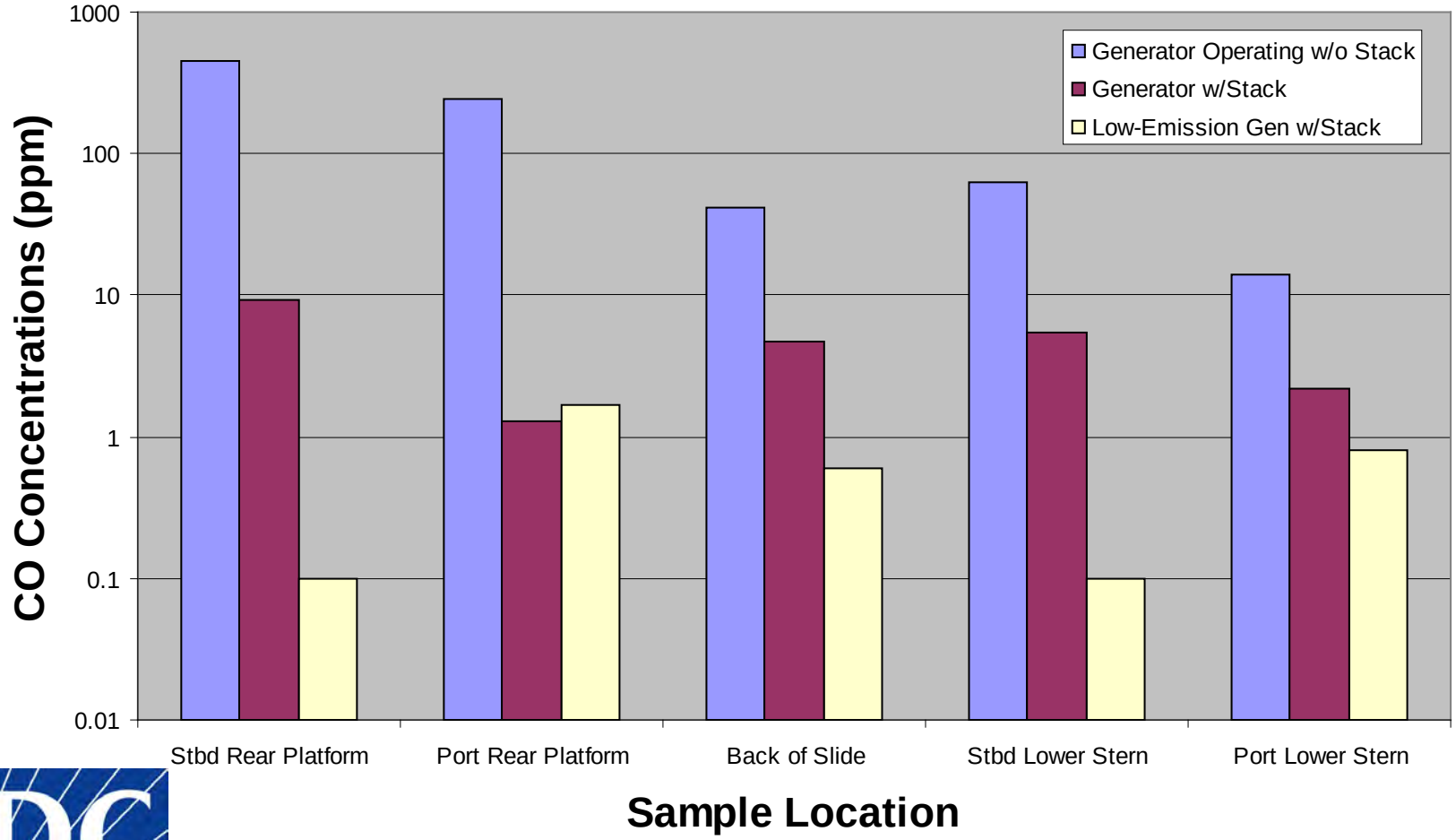
HOUSEBOAT WITHOUT EMISSION CONTROL DEVICE



Conclusions

- The EFI catalyst equipped generators resulted in low CO emissions and indicated safe levels in potentially occupied areas around the boat for either exhaust configuration
- Initial cold measurements were high directly in the stack (11%)
  - Then dramatically reduced to approximately 200 ppm (directly in the stack) after approximately 5 minutes
- Maintenance is important for the performance of this technology
- Use of vertical stack is a good redundant safety measure

Voluntary and Regulatory actions

- **ABYC issued a standard on exhaust configuration and emissions control (ABYC P-1)**
- **EPA finalized a new emission control program to reduce hydrocarbon, nitrogen oxide, and carbon monoxide emissions from marine spark-ignition engines.**
  - **New exhaust emissions standards effect 2010 model year.**
    - **Spark-ignition marine generators – 5 g/KW-hr**
- **National Park Service issued new requirements in 2012 for concession boat rental and marina operations to prevent CO poisoning**

CDC CO Poisoning Web Resources

- http://www.cdc.gov/co/default.htm
- http://www.cdc.gov/niosh/topics/coboating/
- http://www.cdc.gov/co/boating.htm
- http://www.cdc.gov/niosh/topics/co/default.html

Carbon Monoxide Sensing Technology Overview

3.17.2016

Peter Hsi, PhD
Senior Fellow, Director of Advance Development
Honeywell Analytics

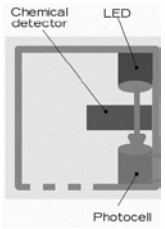
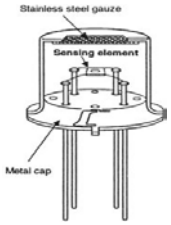
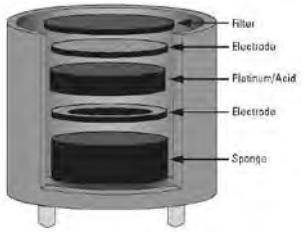
Honeywell

Topics to be covered

- Overview of the available technology
- CO gas monitoring products
- Considerations for CO detection
- Considerations for portable generators
- New sensing and enabling technologies
- Recommendations and actions

Honeywell

CO Sensing Technologies

Technology	Opto-chemical/ Biomimetic	Metal Oxide	Electrochemical
Detection Principle			
Advantages	• good selectivity • Poison resistance • Shock resistance • Pressure range	• long life • low cost • cold temperature	• low power • fast response • accurate • high sensitivity • linear • low cross sensitivity
Disadvantages	• sensitivity • power • slow response & recovery • false alarms • limited life	• Sensitivity • high cross sensitivity • high power • non-linear • Drift • prone to poisoning • interference	• cold temperature • simplicity of design • Operating temperature • Pressure range
Operating Life	5 to 7 Years	5 to 7 Years	6 to 10 Years

Electrochemical technology is now dominant in US and Europe market

Carbon Monoxide Monitor Products

Connected CO monitor
- line powered
- connected to panel
- UL2075

Self-contained CO monitor
- battery powered
- UL2034

Alarm Threshold:
30 ppm no less than 30 days
70 ppm 60 to 240 minutes
150 ppm 10 to 50 minutes
400 ppm 4 to 15 minutes

Personal CO monitor
- 2 year battery life
- lapel/ belt worn
- response time <30 sec
- UL913 Intrinsic Safety

Alarm Threshold:
35 ppm low alarm
50 ppm high alarm

Nest Smoke/CO monitor
- Wi-Fi / smart phone connection

Honeywell

Considerations for CO Detection

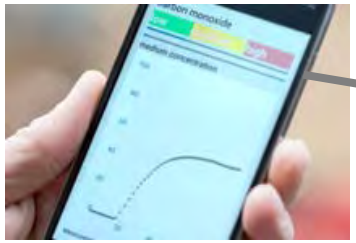
- Response time
- Operating temperature
- Operating life
- Robustness and ruggedness
- Maintenance and calibration
- Operating power

Considerations for Portable Generators

- The right CO sensor
- Auto shut-off feature
- Local or remote CO sensing / shut-off
- Alternative power source
- Alarm Limits

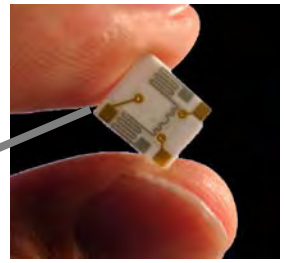
New Sensing & Enabling Technologies

- **MEMS or Printable CO sensor technology:**
  - miniature, thin, solid-sate or solid polymer based sensor
  - low power, robust sensors, mass produced at very low cost
  - smart interface & wireless capability



Real-time data displayed for wearer

Environmental air monitoring application



Sensor: wearable with wireless connectivity to Smartphone

- **Low power wireless radio & IOT technology:**
  - Bluetooth Low Energy (BLE), low power Wi-Fi and mesh radio enable battery powered device to be connected ubiquitously
  - Smart and connected “edge” device collect sensor data

Smart thermostat

Smart light bulb

- **Energy Harvesting technology:**
  - derive & store electrical energy from ambient energy sources: light, motion/ vibration, heat, RF, etc. to power small electronics devices

Solar panel

Vibration AA battery

TE generator

Honeywell

Recommendations and Actions

- **There is a cost effective solution today**
  - ✓electrochemical CO sensor is mature & ready
  - ✓in situ or remote CO monitor can be developed
  - ✓generate alarm or shut off generator automatically
- **What is the follow up actions?**
  - ✓additional feasibility testing of CO sensor under real life and extreme operation conditions of portable generator
  - ✓brainstorm product ideas

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GROUP

PGMA Technical Summit
3-17-2016

OUTDOOR PRODUCTS GROUP

Chairman's Challenge: "Prevent Injuries, Save Lives & Make a Real Difference"

PROBLEM: CO POISONING

Carbon Monoxide (CO), a colorless, odorless gas, is the "invisible" killer responsible for more than **400 deaths** annually.[11]

Carbon monoxide is produced by burning fuel. Therefore, any fuel-burning appliance in your home is a potential CO source. Improperly operating appliances can produce fatal CO concentrations in your home.

CHALLENGES

- Invent a cover or activation switch for the ignition of a portable generator that requires the operator to interact with a danger label or some other educating device before turning the generator on.
- Invent a generator that cannot be operated inside.
- Invent a generator that does not release carbon monoxide.
- Invent a sensor for appliances, such as furnaces, that alarms and/or shuts off fuel flow if the appliance is operating improperly.
- Design a carbon monoxide alarm that has visual and auditory indicators that are clear and easy to understand.

10

Invent a generator that does not release carbon monoxide.

US Consumer Product Safety Commission
Elliot F. Kaye – Chairman, August 2015

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Why TTi has focused on Low CO Emissions Technology?

Low CO Emissions Technology

- Detailed report by UofA, CPSC & NIST on the conversion of a generator to Low CO emissions
- EPA Exhaust Emissions Methods have been around for decades. Expensive measuring equipment already available ($Millions) by many OEMs/Labs
- Automotive Engineers (talent) readily available with similar experience

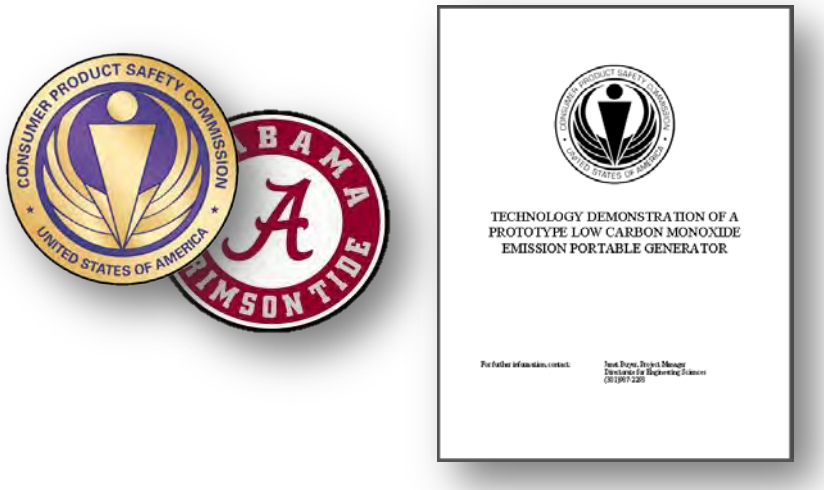
- Houseboat & Fork Lift Industry faced CO exhaust issues and provide examples of limiting CO emissions success
- UL2201 Subtask Group preliminary standard & Discussions available as reference. 90% ready

CO Shutoff Technology

(when used in-doors)

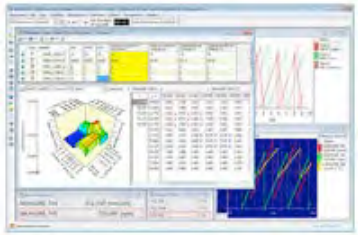
- Limited experience among staff relating to detecting atmospheric CO levels
- Limited familiarity with testing methods to detect high CO
- Limited testing equipment available at generator OEM facilities
- Limited/No progress on a preliminary standard and/or discussion on the topic
- Limited success by UofA, CPSC, & NIST trying to demonstrate the technology

Is it possible to make a LOW CO Emissions Generator?



TTi EFI – SYSTEM DESCRIPTION

FUEL INJECTION

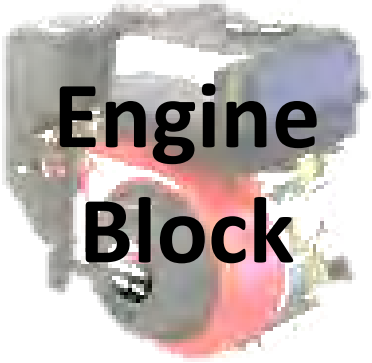


Throttle Body / MCU / Tuning

Temperature Sensors

Battery

Flywheel Tone Ring, RPM sensor



Engine Block

Fuel Pump

O2 Sensor

Fuel Injector

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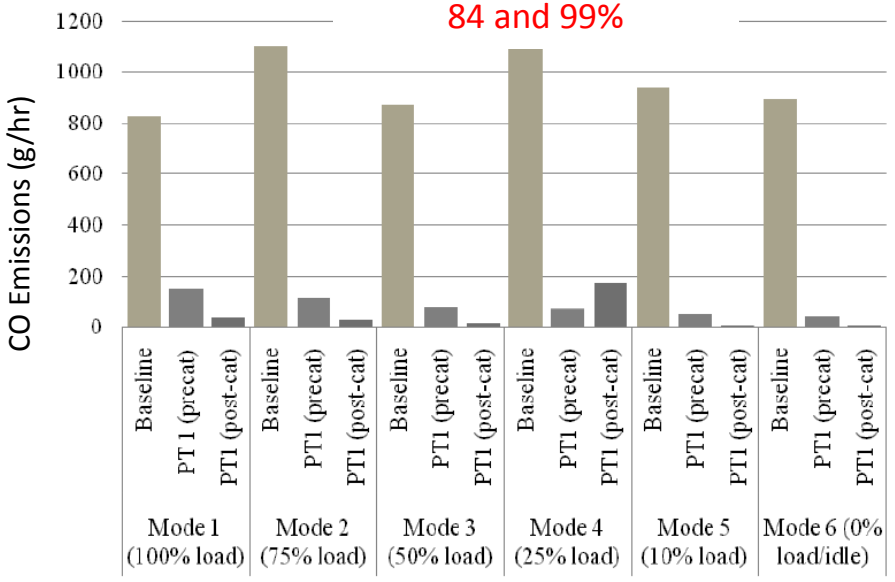
Low CO Generator Emissions – Ambient (EPA) Test Results

Low CO Emissions Generator

CO Reduction between 84 and 99%

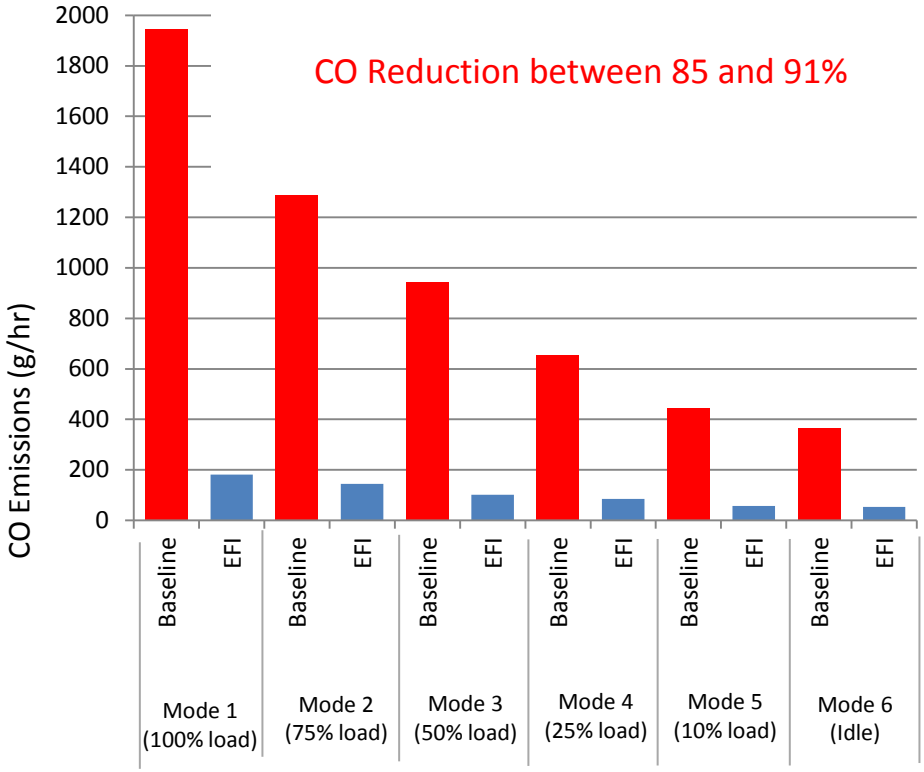


EPA Modal Setting

- 500hr Emission Test (EFI)
- **EPA Phase II**
- 7.6 KW Estimated Engine Power

Low CO Emissions Generator

CO Reduction between 85 and 91%



EPA Modal Setting

- 500hr Emission Test (EFI)
- **EPA Phase III** ←
- 8.9 KW Estimated Engine Power

CPSC Technology Demonstration of a Prototype Low CO Emissions Portable Generator
Fig. 19: Modal CO Emissions Data for Prototype & Baseline Generators

TTI LOW CO GENERATORS – ENCLOSED CONDITIONS

SHED Testing

SHED Testing

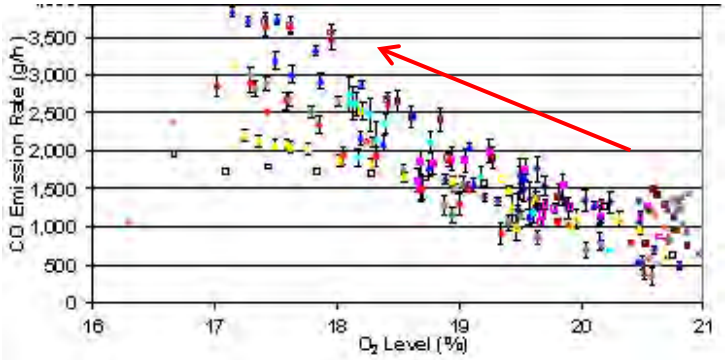
GARAGE Testing

ENCLOSED GENERATORS – CO REACTION TO SHED TESTING

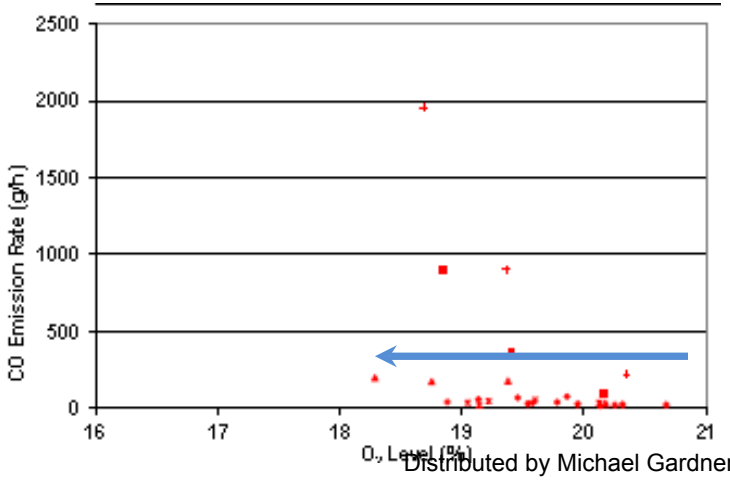
NIST

Shed Test - Carbureted Engine Emissions vs. EFI Engine

Carbureted Engine Emissions

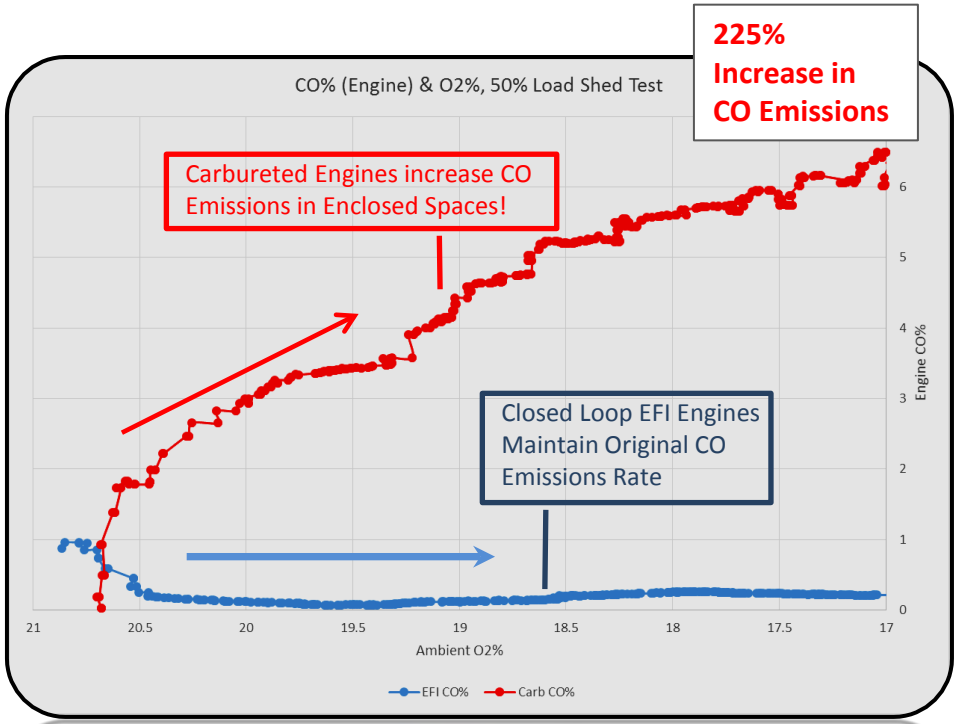


Closed Loop EFI Engine Emissions



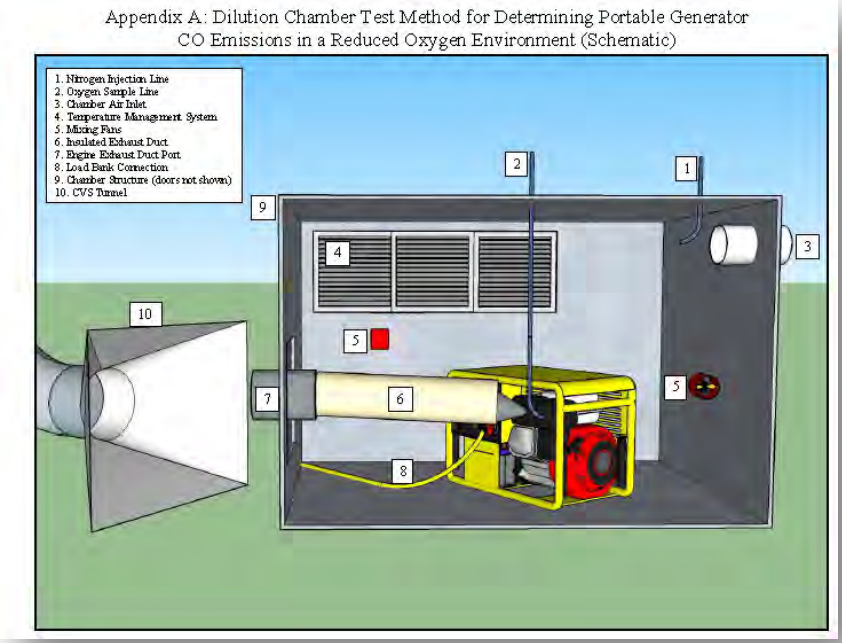
TTI

Shed Test - Carbureted Engine Emissions vs. EFI Engine



TTI LOW CO GENERATORS – ENCLOSED CONDITIONS

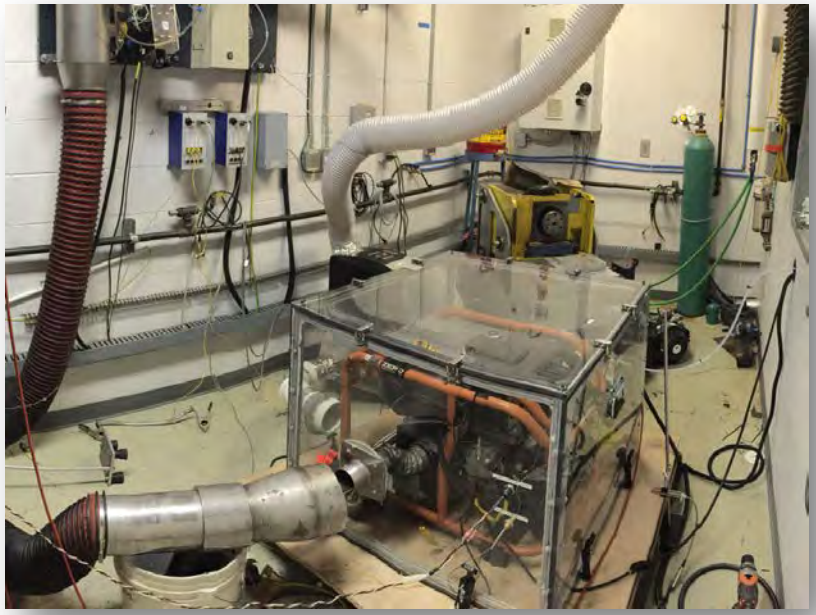
Nitrogen Chamber Testing



Discussion from UL Taskgroup resulted in above proposal/schematic (Oct. 16, 2015)

Nitrogen Chamber Testing

TTi constructed version



- Uses same EPA Certified Emissions Equipment (AVL)
- 3 weeks construction, approx. $10K USD

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TEST METHOD – ENCLOSED CONDITION – NITROGEN CHAMBER

Determine Maximum Continuous Output Power[1]

Dry Bulb Room Temperature 59-95F. Oxygen >20.5%. Barometric Pressure 950-1050 hPa. Relative Humidity 0-75%

1- Determine Maximum Continuous Output Power of Generator

Step 2, First Cycle:	Set to 100% of output power determined in Step 1.
Step 2, Second Cycle:	Set to 75% of output power determined in Step 1.
Step 2, Third Cycle:	Set to 50% of output power determined in Step 1.
Step 2, Fourth Cycle:	Set to 25% of output power determined in Step 1.
Step 2, Fifth Cycle:	Set to 10% of output power determined in Step 1.
Step 2, Sixth Cycle:	Apply 0% (no Load)

2- Set Output Power Level

Set the Generator to desired output power & allow generator to reach Temperature Stabilization[1]
. Do not adjust the generator or loading during Section 3.

Dry Bulb Room Temperature 59-95F. Oxygen >20.5%. Barometric Pressure 950-1050 hPa. Relative Humidity 0-75%

3.1- Adjust Nitrogen Flow

Enclose the Generator and ensure sufficient air circulation. Ensure oxygen levels at Air Intake of Engine are at Ambient (>20.5%)

Dry Bulb Inlet Air Temperature 59-95F. Initial Oxygen >20.5%. Barometric Pressure 950-1050 hPa. Relative Humidity 0-75%

3.2- Measure CO Engine Emissions

Measure CO Emissions of Engine exhaust at set load for 2 minutes per EPA 40 CFR 1065. Engine speed is allowed to vary accordingly.

Dry Bulb Inlet Air Temperature 59-95F. Initial Oxygen >20.5%. Barometric Pressure 950-1050 hPa. Relative Humidity 0-75%. Enclosure CO level less than 400ppm

3.3- Adjust Nitrogen Flow

While Enclosed, adjust Nitrogen Flow until Oxygen levels in the chamber reach 19% +/- 0.25% within 2 inches of Air Intake of Engine.

Dry Bulb Inlet Air Temperature 59-95F. Barometric Pressure 950-1050 hPa. Relative Humidity 0-75%

3.4- Measure CO Engine Emissions

Measure CO Emissions of Engine exhaust at set load for 2 minutes per EPA 40 CFR 1065. Engine speed is allowed to vary accordingly.

Dry Bulb Inlet Air Temperature 59-95F. Oxygen 19% (or Midpoint). Barometric Pressure 950-1050 hPa. Relative Humidity 0-75%. Enclosure CO level less than 400ppm

3.5- Adjust Nitrogen Flow

While Enclosed, adjust Nitrogen Flow until Oxygen levels in the chamber reach 17% +/- 0.25% within 2 inches of Air Intake of Engine

Dry Bulb Inlet Air Temperature 59-95F. Barometric Pressure 950-1050 hPa. Relative Humidity 0-75%

3.6- Measure CO Engine Emissions

Measure co Emissions of Engine exhaust at set load for 2 minutes per EPA 40 CFR 1065. Engine speed is allowed to vary accordingly.

Dry Bulb Inlet Air Temperature 59-95F. Oxygen lowest capable or to 17%. Barometric Pressure 950-1050 hPa. Relative Humidity 0-75%. Enclosure CO level less than 400ppm

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CARB TEST log sheet – ENCLOSED CONDITION – NITROGEN CHAMBER

GENERATOR CARBON MONOXIDE (g/hr) EMISSION LEVELS

CONTINUOUS OUTPUT POWER at Ambient	INLET AIR OXYGEN CONCENTRATION LEVEL: Ambient (>20.5%)	19%	17%	CO Emissions Rate
100%	2036 g/hr	3060 g/hr	2541 g/hr	
75%	1740 g/hr	2552 g/hr	2946 g/hr	
50%	1236 g/hr	2250 g/hr	2658 g/hr	
25%	1103 g/hr	1664 g/hr	2287 g/hr	
10%	2429 g/hr	2243 g/hr	2250 g/hr	
0%	2189 g/hr	1936 g/hr	1910 g/hr	

*7KW Open Frame Generator, 390cc-420cc class carbureted engine

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EFI TEST log sheet – ENCLOSED CONDITION – NITROGEN CHAMBER

GENERATOR CARBON MONOXIDE (g/hr) EMISSION LEVELS

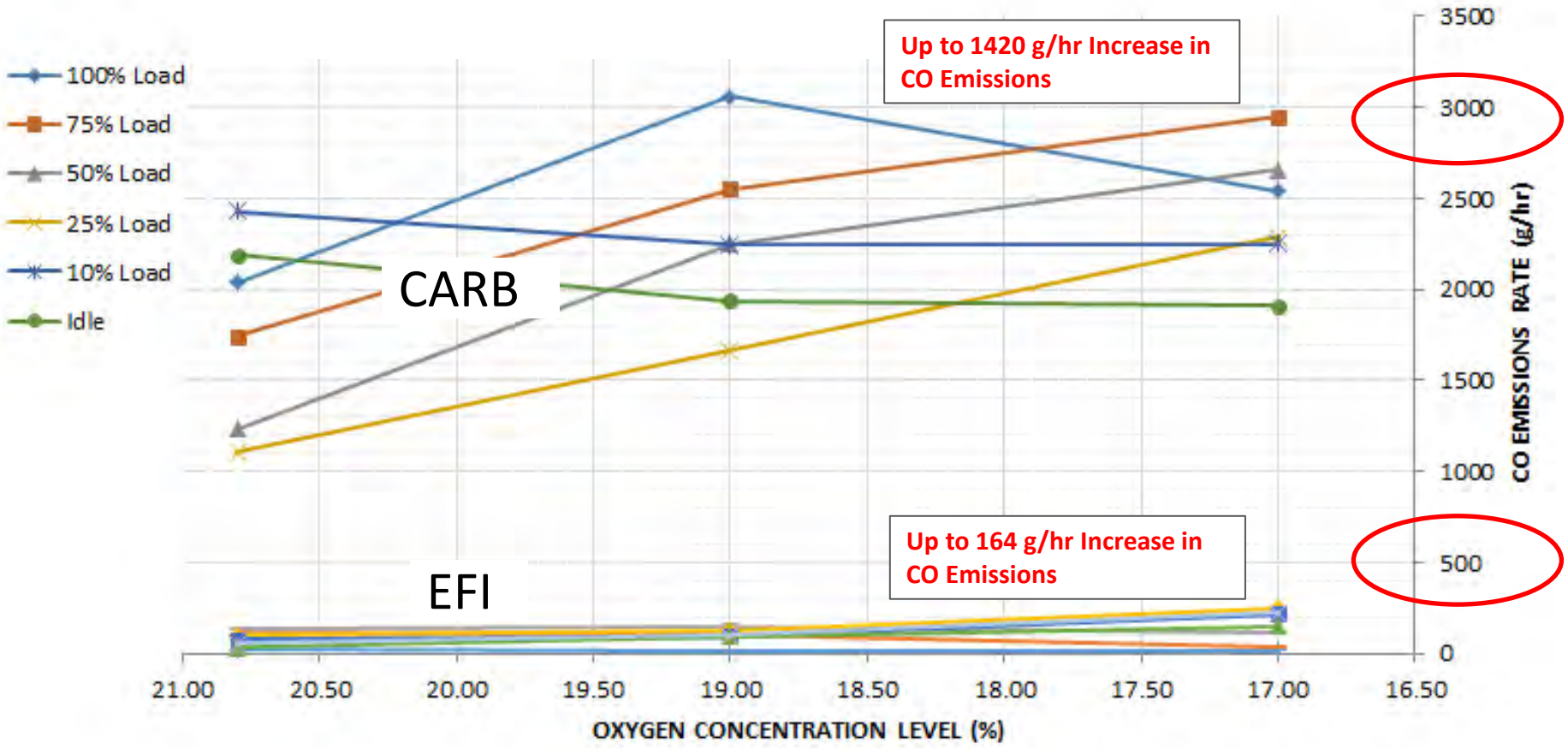
CONTINUOUS OUTPUT POWER at Ambient	INLET AIR OXYGEN CONCENTRATION LEVEL: Ambient (>20.5%)	19%	17%
100%	113 g/hr	108 g/hr	36 g/hr
75%	137 g/hr	151 g/hr	112 g/hr
50%	102 g/hr	131 g/hr	250 g/hr
25%	79 g/hr	97 g/hr	219 g/hr
10%	36 g/hr	95 g/hr	149 g/hr
0%	59 g/hr	100 g/hr	223 g/hr

CO Emissions Rate

*7KW Open Frame Generator, 390cc-420cc class EFI engine

COMPARISON – ENCLOSED CONDITION – NITROGEN CHAMBER

CO Emissions Trend at various Load & O2 Levels



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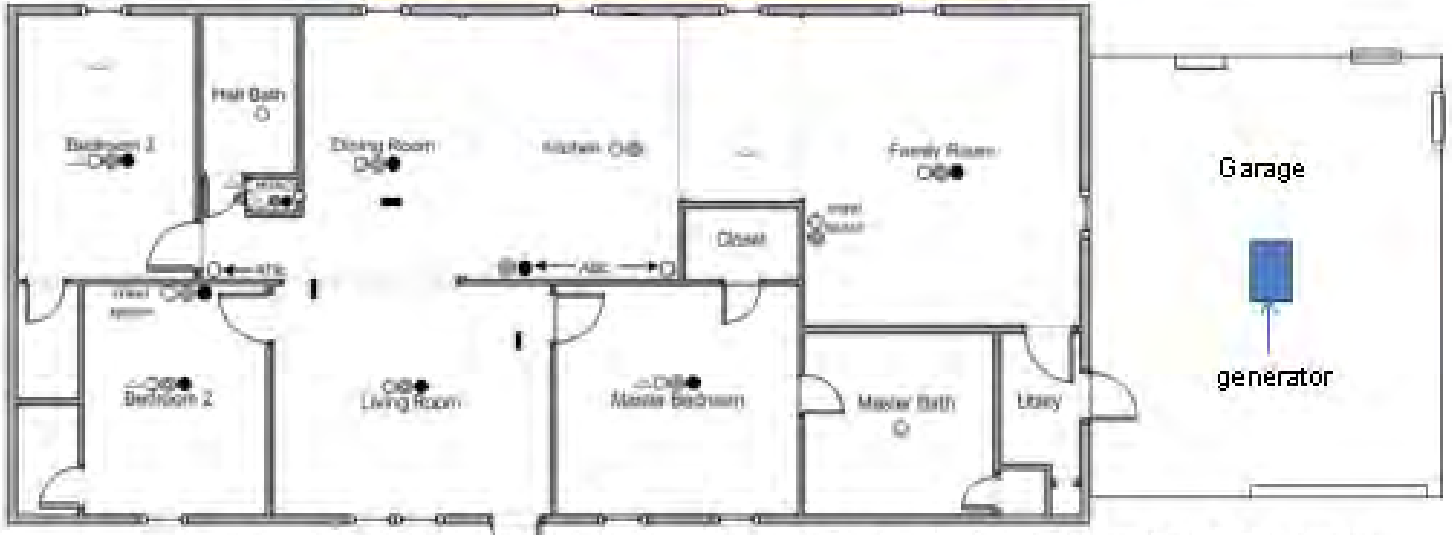
Will a LOW CO Emissions Generator Make a Difference?

(NIST) Generator CO Testing & Simulations

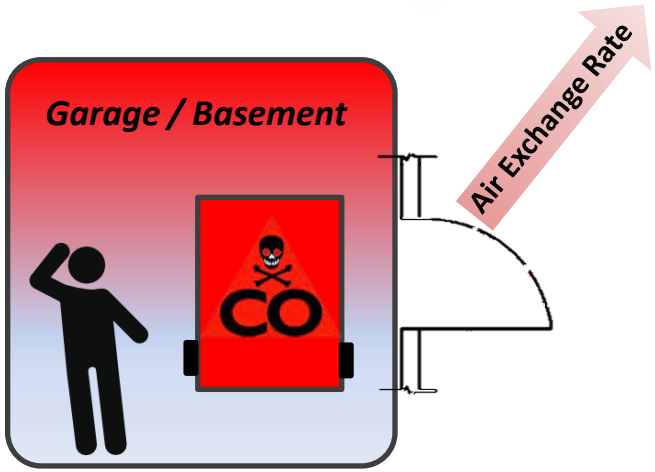
NIST
National Institute of Standards and Technology



4 scenarios tested to compare prototype with catalyst to OEM unit
(varied by positions of bay door, utility door, HVAC fan)

CONTAM Simulation on 87 single-family dwellings. Total of 100,000 individual simulations conducted that cover a range of house layouts, sizes, airtightness, & generator location & CO Emission strength

Generator Misuse in Enclosed Spaces - Garage/Basement



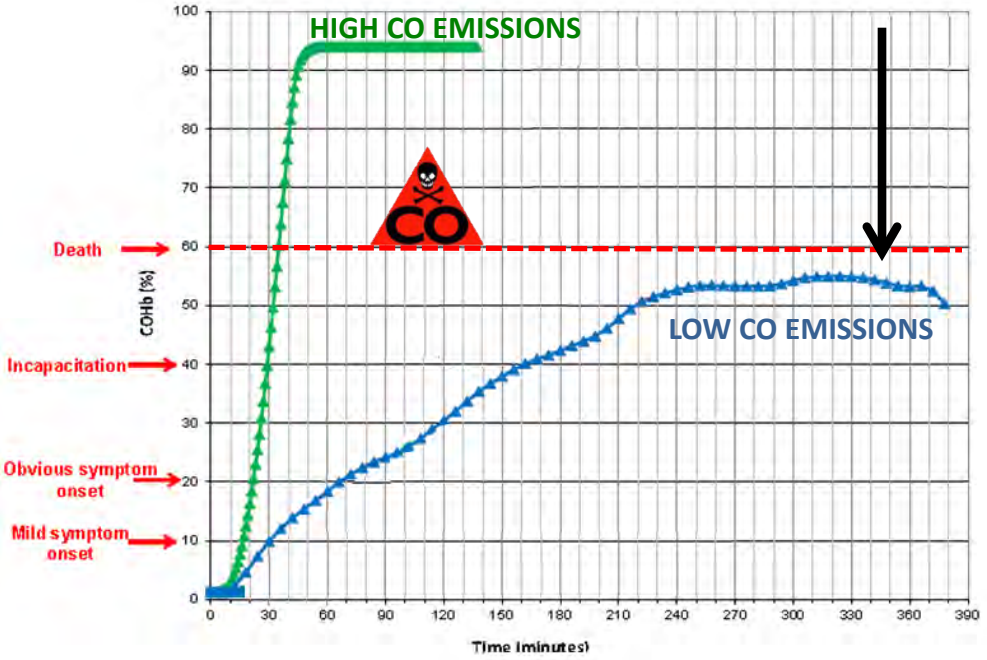
COhb % Equation =

+ GENERATOR CO Emissions Rate

- (Garage Size + Air Exchange Rate)

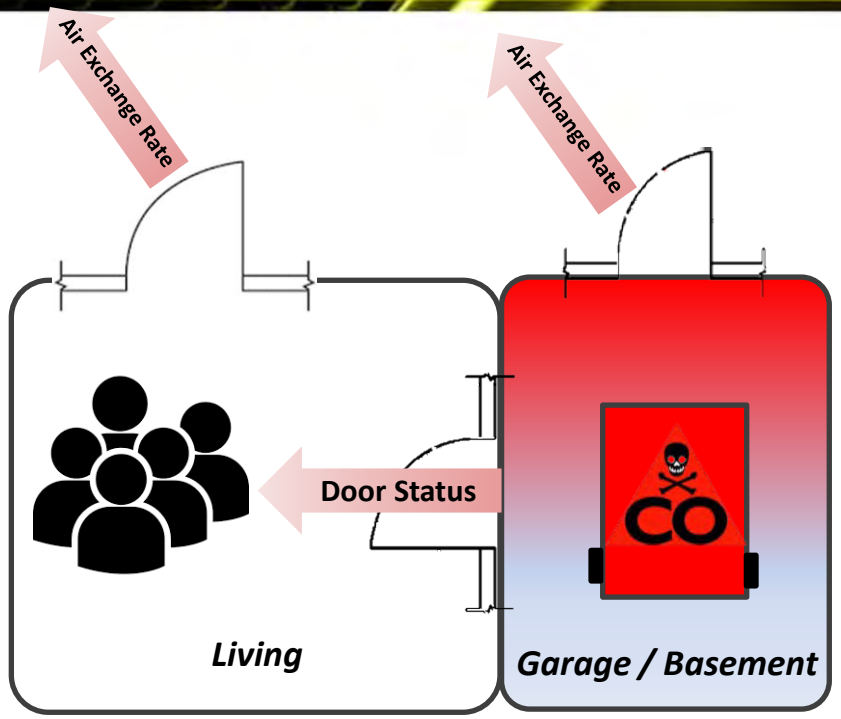
+ Time

NIST National Institute of Standards and Technology



US Consumer Product Safety Commission
Janet Buyer, October 2012 Presentation
(University of Alabama Low CO Prototype)

Generator Misuse in Enclosed Spaces - Living Room



COhb % Equation =

+ GENERATOR CO Emissions Rate

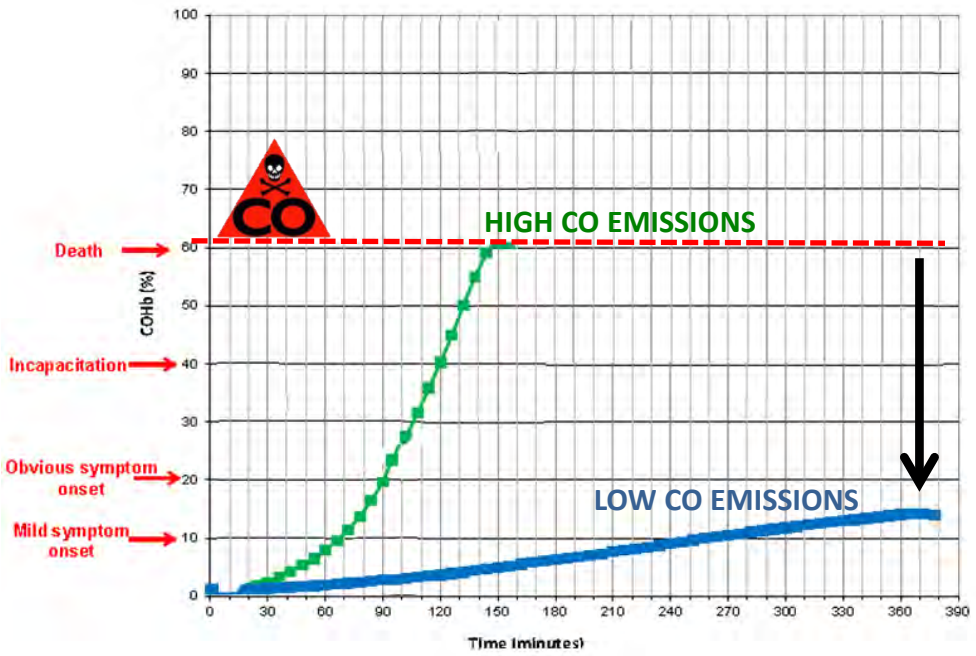
- (Garage Size + Air Exchange Rate)

- Door Opening Status

- (Living Size + Air Exchange Rate)

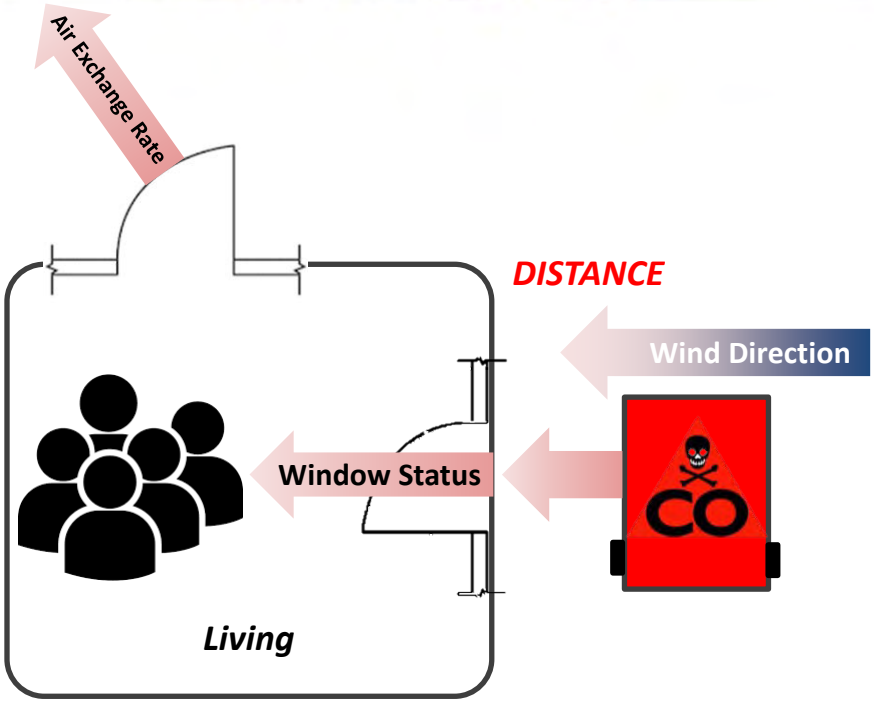
+ Time

NIST National Institute of Standards and Technology



US Consumer Product Safety Commission
Janet Buyer, October 2012 Presentation
(University of Alabama Low CO Prototype)

Generator Misuse – Outside Near Window / Door



COhb % Equation =

+ GENERATOR CO Emissions Rate

- Wind Direction / Speed

- Distance to Window/Door

- Window Opening Status

- (Living Size + Air Exchange Rate)

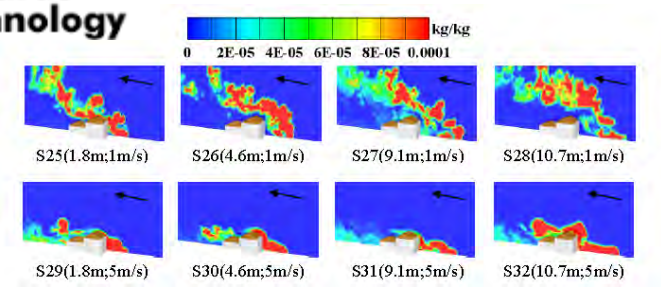
+ Time

Centers for Disease Control and Prevention
National Center for Health Statistics

PORTABLE GENERATORS

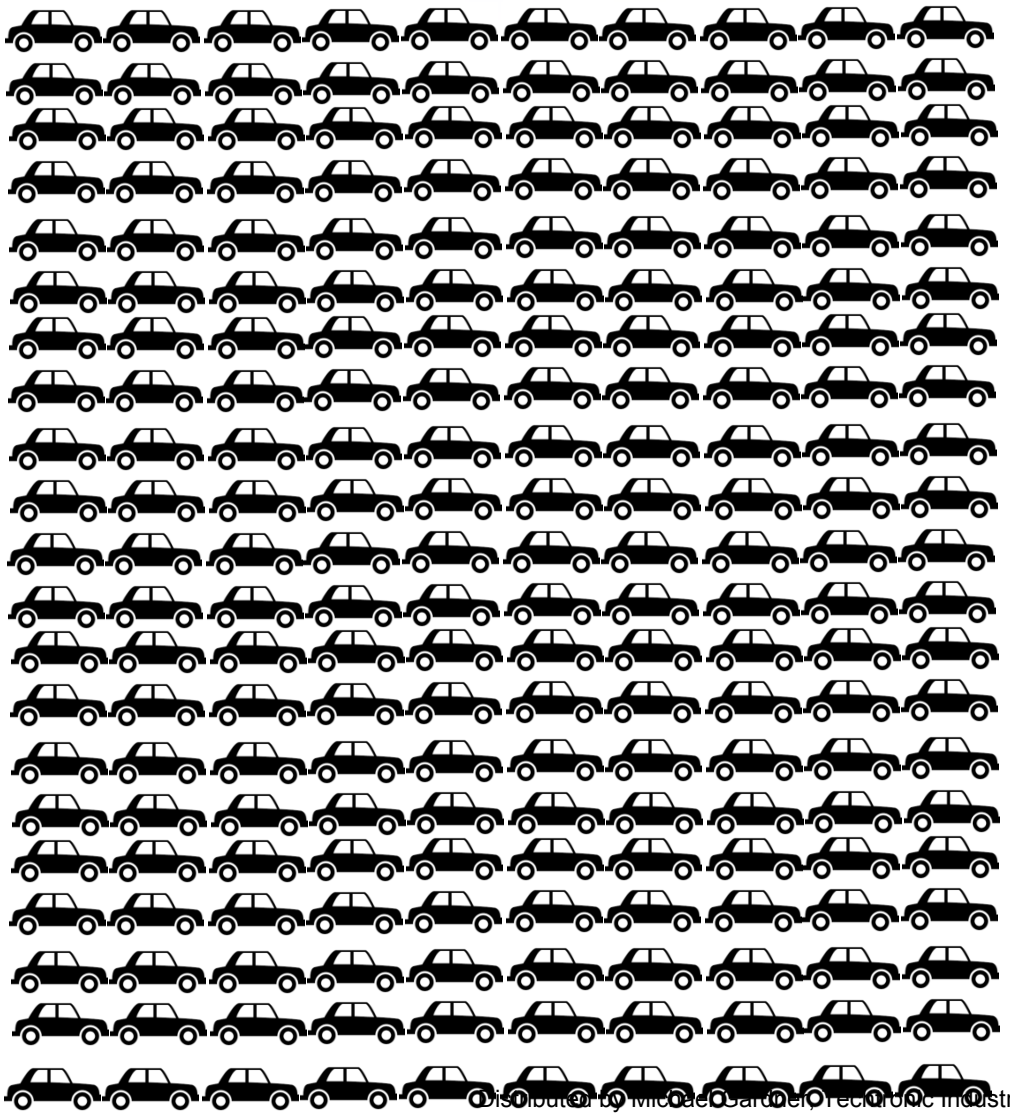
- ✔ Never use a generator inside your home or garage, even if doors and windows are open.
- ✔ Only use generators outside, more than 20 feet away from your home, doors, and windows.

National Institute of Standards and Technology



CO Exhaust Comparison & Perspective

~400 Modern Cars



1 Current 6KW Carbureted Generator

(without EFI Low CO Technology)

Quantification of Variability & Uncertainty in Emissions Factors (99-267). NC State

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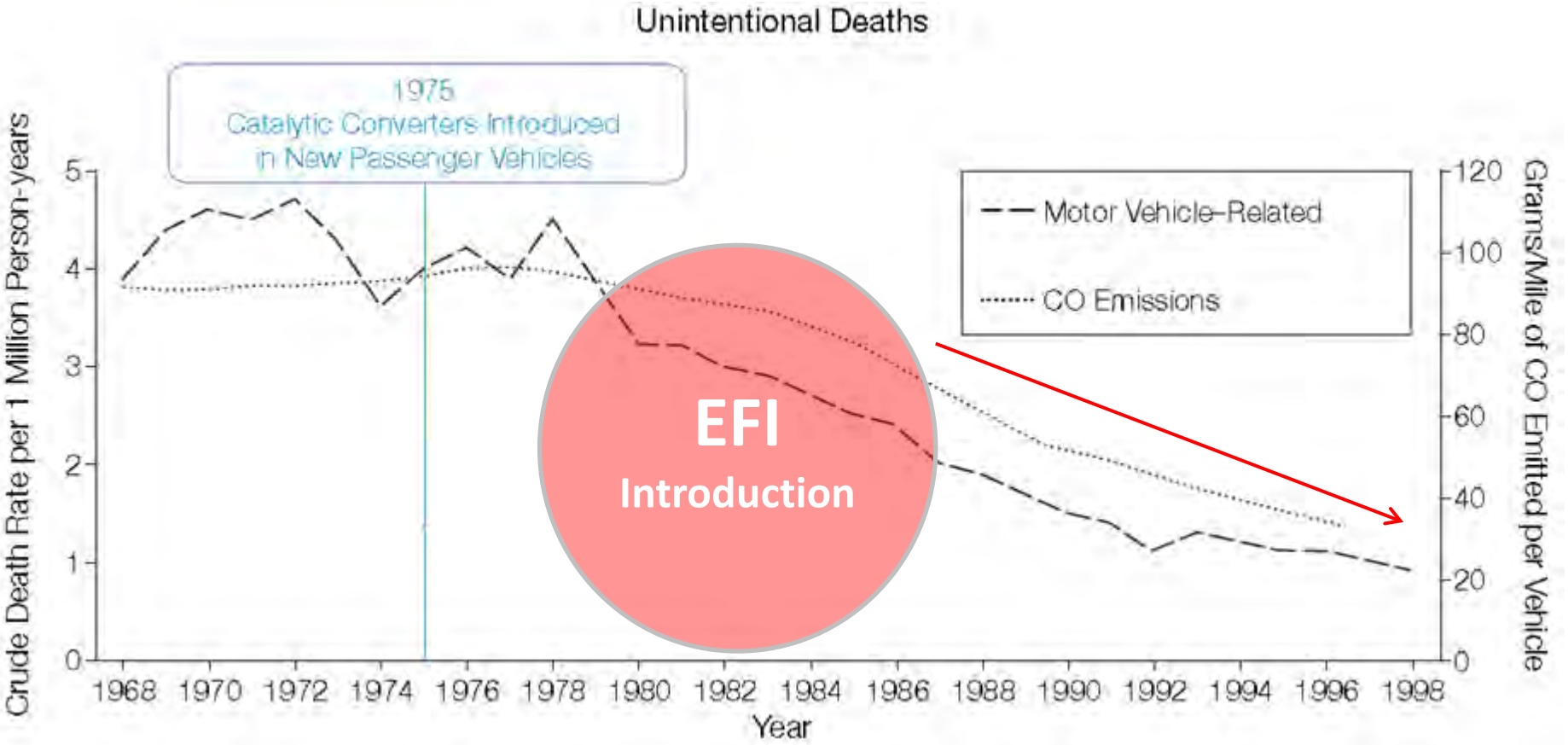
Automotive Emissions – Correlation Comparison



From: **National Vehicle Emissions Policies and Practices and Declining US Carbon Monoxide–Related Mortality**

JAMA. 2002;288(8):988-995. doi:10.1001/jama.288.8.988

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SUMMARY on Low CO Generator Emissions

- ✓ Is it possible to make a Low CO Generator with a single cylinder, air cooled engine?
- ✓ Will a Low CO generator make a difference in lowering the incidents of CO poisonings?
- ? Can the Low CO performance remain consistent & Durability of generator be maintained during high volume production?
- ? How much more are consumers willing to pay for Low CO Emissions Technology?
- ? Can a CO Shutoff Technology be developed using Low CO Emissions Technology?

TTi encourages industry partners to work together with the PGMA, UL & CPSC to support a LOW CO EMISSIONS solution.

GenTent Safety Canopies

Keeping Families Safe by Weatherproofing Portable Power Since 2012

Distributed by Mark Carpenter, GenTent Safety Canopies, at PGMA Public Meeting 9/17/2016

Topics

- Company Intro
- Generator Tent Need and Requirements
- Alternatives
- Generator Tent method design elements
- Mounting Challenges and Solutions
- Sample Applications
- How well does it work?

Company Overview

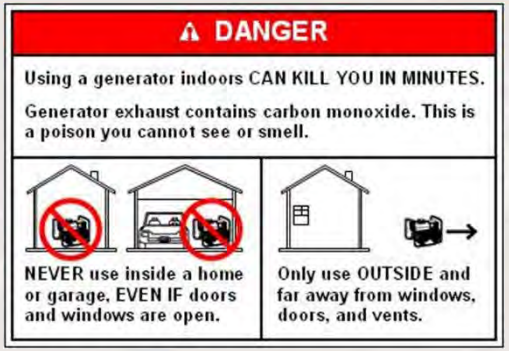
- Established 2011, New Hampshire
- Portable Generator Accessory Market
  - Emergency Backup Portable Generator Safety in wet weather
  - 2015: Recreational portable generator Safety in wet weather
- Product launch March 2012
  - Kept hundreds safe during Sandy in NY/NJ/CT
  - Approaching 10,000 GenTents Sold including National Guard CERF-P and PG&E
- 5-Star customer avg rated (98% of over 600 Reviews)

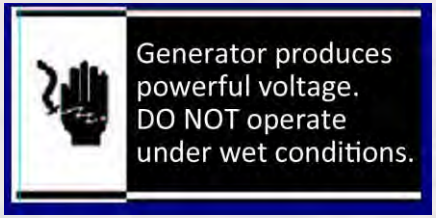
- U.S. Patent 8,997,769, April 2015
  - Fundamental Method Patent - self-attaching protective cover for portable electrical device
- U.S. Patent 9,271,416, February 2015
  - System Patent – elements of self-attaching protective cover for portable electrical device
- Trademarks
  - GenTent®
  - StormBracer®
  - Weatherproof Your Power™

Run Generators Outside – The Need

Problem Statement:

How to enable portable generators to run in wet weather while avoiding generator damage and electrocution hazards





Portable Generators usage conundrum

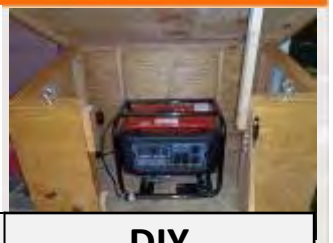
- Do not use indoors -> CO Poisoning hazard
- Do not use in wet weather -> Electrocution (and generator damage) hazard

Needs a New Product Category (Generator Tent)

- Portable accessory that waterproofs sensitive areas
- Easy to install and keeps generator portable
- Fits on nearly all portable generators
- Maintains portable generator cooling and airflow
- Can withstand severe wet weather
- Affordable
- *Does not introduce new safety concerns*

Distributed by Mark Carpenter, GenTent Safety Canopies, at PGMA Public Meeting 9/17/2016

Comparing The Options



		Steel Enclosure	Retrofit Plastic Shed	Pop-Up 10x10 Canopy	DIY Dog House
Accessory Product?	**Yes**	No	No	No	No
Waterproofs Severe Wet Weather?	**Yes**	Yes	Yes	No	Yes
Withstand Winds up to 70MPH?	**Yes**	Yes	Yes	No (20 MPH Max)	Yes
Easy to Install	**Yes** (10 Min Avg)	No (Professional Install Req'd)	No (2-4 hours)	Yes (10 Min Avg)	No (4-8 hours)
Generator Stays Portable	**Yes**	No	No	Yes	No
Generator Naturally Cools	**Yes**	Yes	No (dangerous)	Yes	No (dangerous)
Fits Nearly All Portable Generators	**Yes**	No	No	Yes	No
Percentage of Portable Generator Purchase	**5%-20%**	55%-120%	50%-100%	4%-30%	4%-40%

Distributed by Mark Carpenter, GenTent Safety Canopies, at PGMA Public Meeting 9/17/2016

Generator Tent Systems Approach

	Create Mount	Install Frame	Install Canopy
Portables Use GenTent Clamp System 			
Inverters Use GenTent Strap System 			
System Design Elements Work Together	**Adjusting Robust Mount System**	**Exerts outward and upward forces**	**Constrains and stabilizes the mount/frame**

Distributed by Mark Carpenter, GenTent Safety Canopies, at PGMA Public Meeting 9/17/2016

Generator Tent Mounting Challenges

Portable Generators

- **Exposed vertical frames**
- **Round or Square Tubular frames**
- **Attached panels / heat shields**
- **Varied electrical panel to exhaust side & height locations**
- **Wide range of frame sizes**

Inverter Generators

- **Fully encased**
- **Case corners omni-angular**
- **Single and Parallel setups**
- **Varied electrical panel to exhaust side & height locations**
- **Wide range of frame sizes**

Generator Tent Mounting Challenges

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- Exposed vertical frames
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Generator Tent Mounting Challenges

(long side/rear)

(short side/adjacent)

(long side/adjacent)

(short side/rear)

Portable Generators

- Exposed vertical frames
- Round or Square Tubular frames
- Attached panels / heat shields
- Varied electrical panel to exhaust side & height locations
- Wide range of frame sizes

Inverter Generators

- Fully encased
- Case corners omni-angular
- Single and Parallel setups
- Varied electrical panel to exhaust side & height locations
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Generator Tent Mounting Challenges

Portable Generators

- Exposed vertical frames
- Round or Square Tubular frames
- Attached panels / heat shields
- No consistent electrical panel to exhaust orientation
- Wide range of frame sizes

Inverter Generators

- Fully encased
- Case corners omni-angular
- Single and Parallel setups
- No consistent electrical panel to exhaust orientation
- Wide range of frame sizes

Generator Tent Mounting Challenges

And Virtually Any Combination of Differences

Generator Tent Mounting

Portables

Universal Clamping System

Inverters

Universal Strapping System

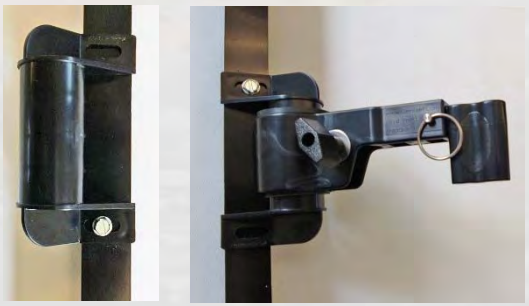
Generator Tent Mounting - Portable Generator

Clamp Mount Adjustability

- "Inward" for smaller perimeters
- Up & Down on vertical frame
- Side to side for Canopy Ratio
- Frame diameters with Sleeve Inserts

Adapter for Square and Blocked Frames

- Square to round mounting point
- Gets around connected panels
- Gets around heat shields

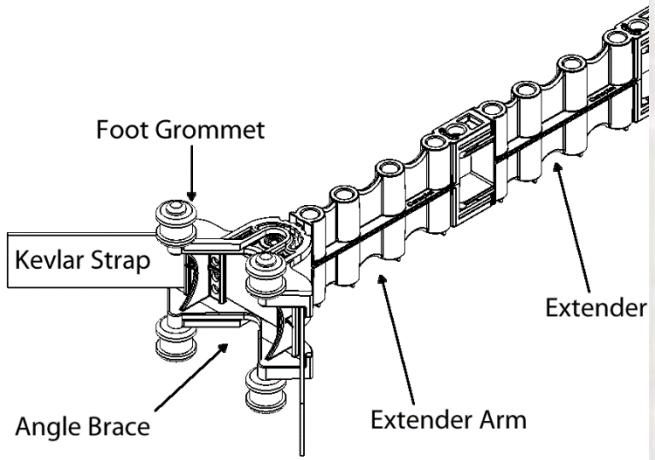


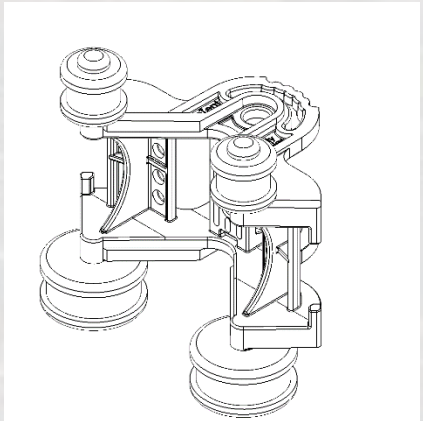
Limit Canopy Sizes and Focus on Adjustable Mounting Systems

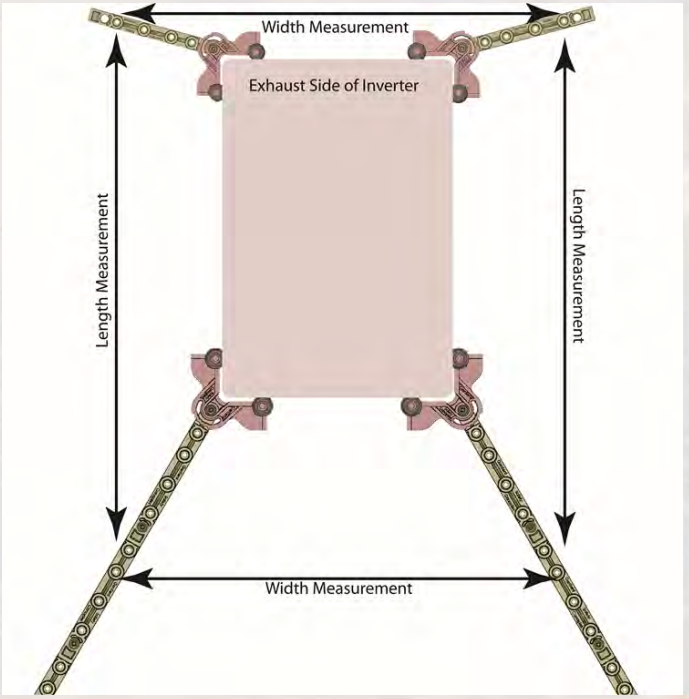
Generator Tent Mounting - Inverter Generator

Strap Mount Adjustability

- **Two lengths of buckle strap**
- **“Outward” via extension arms**
- **Side to side via ratcheting spring loaded corner brace**
- **Case curvature accommodated via foot grommet sizes**
- **Offset installation moves exhaust to the edge**







Generator Tent - Application Breadth



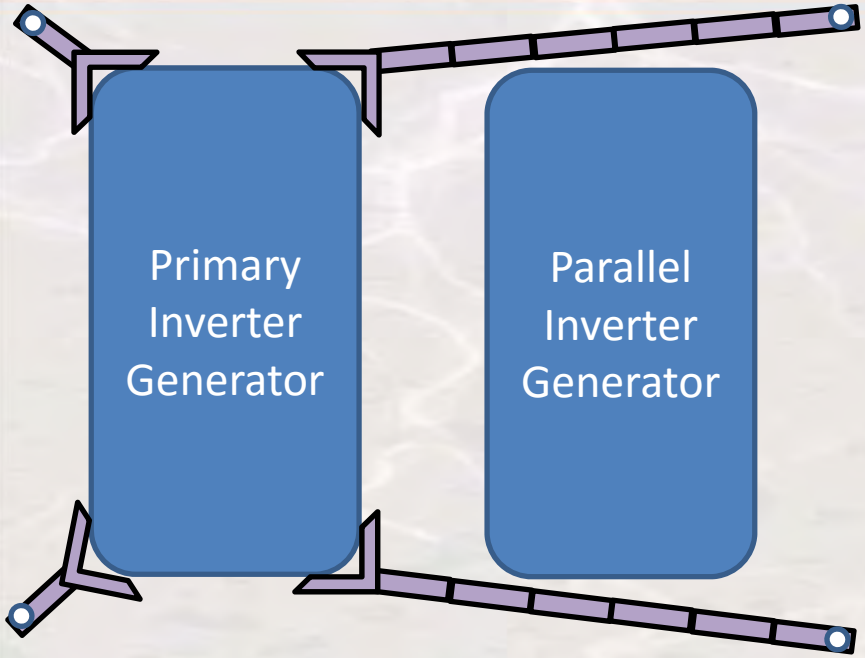







Distributed by Mark Carpenter, GenTent Safety Canopies, at PGMA Public Meeting 9/17/2016

GenTent Parallel Inverter Installation



Independent Claims Testing

Testing Overview

GenTent 10k StormBracer Edition
Westinghouse WH7500E portable generator
Test occurred between January and March of 2015

Claims under test

- Outlet Moisture Protection
- Snow Load
- Wind Survivability
- Generator Cooling Interference
- Impeding Generator Air Intake
- Materials Auto-Ignition Resistance

Test Results Summary

As tested by 360° Product Testing, the GenTent operates in winds of 70 MPH, supports 55.5 lbs. of load, remains watertight in the equivalent of 24 inches of rain per hour, does not change the cooling profile or modify air intake of the [tested] portable generator in any way, and product materials will not auto-ignite even when exposed to high temperature surfaces typical of a hot muffler.

How can we work together to develop this market?

Mark Carpenter, Owner and Inventor
Mark.carpenter@gentent.com
(O) 781-334-8368
(M) 925-389-8841

Catalyst Control of CO from Portable Generators

Kevin Hallstrom
BASF Catalysts

PGMA Technical Summit
Washington, D.C.
March 17, 2016

kevin.hallstrom@basf.com
www.meca.org

Manufacturers of Emission Controls Association

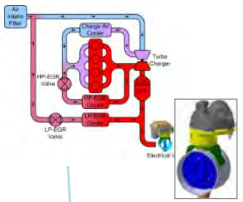
- Technology voice for the emission control industry with air regulatory agencies and stakeholders since 1976
- 39 member companies commercializing emission control technologies for all sizes of internal combustion engines
- Combustion and exhaust emission control technologies:
  - Catalytic Converters (All Fuels)
  - Diesel and Gasoline Particulate Filters
  - Exhaust Thermal Management
  - Evaporative Emission Control
  - Engine/Combustion Efficiency
  - OBD Sensors
  - Fuel Cell and Battery Technologies

MECA members have extensive technical and manufacturing experience in the safe application of catalysts to a wide variety of on-road and off-road, small displacement, spark-ignited engines.

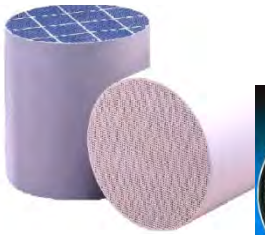
MECA Portfolio Covers Criteria and GHG Emission Control Technologies

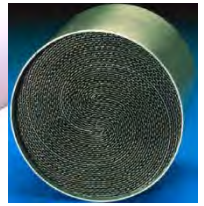
Fuel Combustion Controls

Air Handling



Filters & Substrates

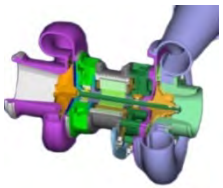


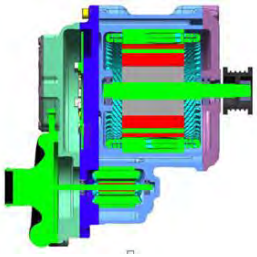


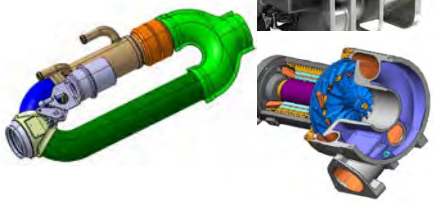
Advanced Exhaust Controls

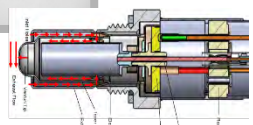
Evaporative Controls

Powertrain Electrification









OBD Sensors

Waste Heat Recovery

Spark-Ignition Portable Generators

- Classified as small SI engines (nonhandheld) by U.S. EPA

Class I (<225 cc)

walk-behind mower

generator

pressure washer

Class II (≥225 cc)

riding mower

zero-turn mower

generator

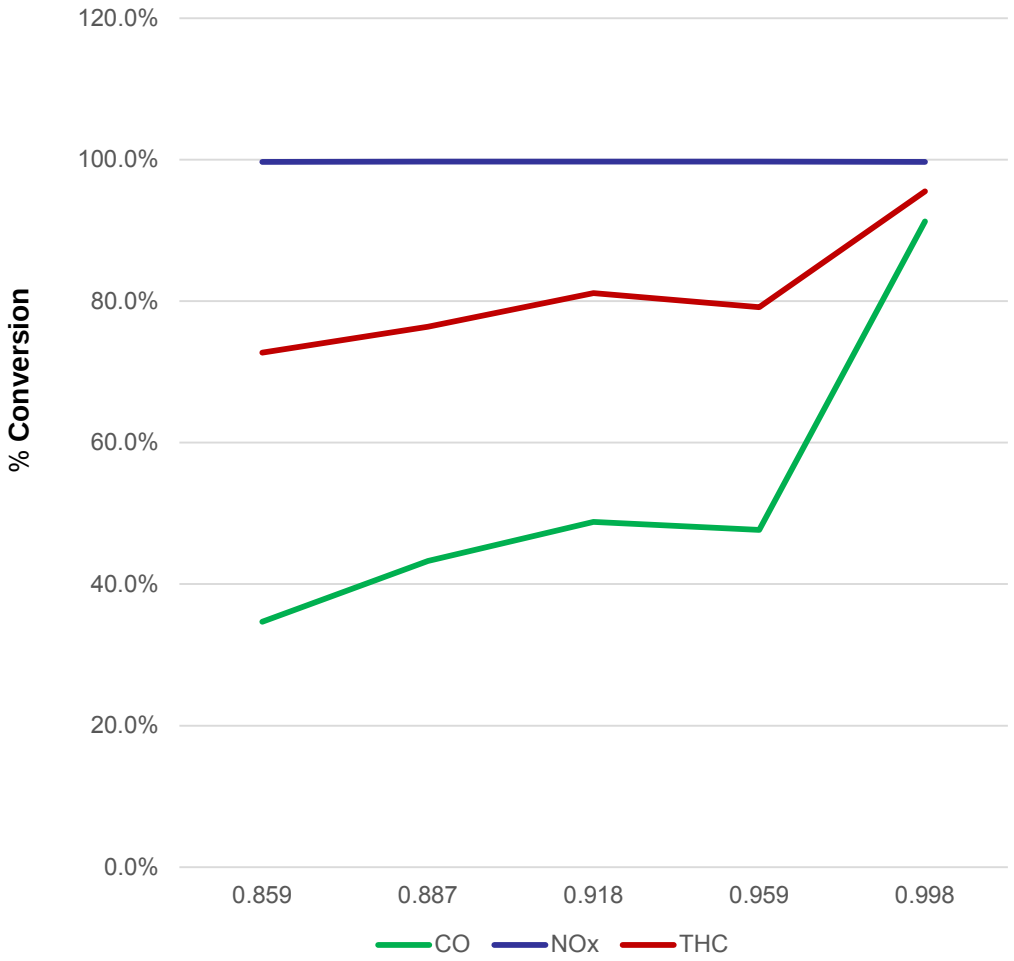
Current U.S. EPA Regulations

- Phase 3 exhaust emission standards for nonroad SI engines 19 kW and below finalized in October 2008
  - EPA expected Class I engines to meet standards through use of catalysts and general engine improvements
  - Mix of technologies expected for Class II engines – general engine improvements, fuel injection, and catalysts

Engine Class	Start Date	HC+NOx (g/kW-hr)	CO (g/kW-hr)	CO (g/kW-hr) (marine generator engines only)	Useful Life – Residential (hours)	Useful Life – Extended Life Residential (hours)	Useful Life – Commercial (hours)
Class I (<225 cc)	2012	10.0	610	5.0	125	250	500
Class II (≥225 cc)	2011	8.0	610	5.0	250	500	1,000

Note: The useful life period is five years or the number of hours of operation (as shown in the table), whichever comes first.

Pt-Rh Catalyst Technology Proven Effective for CO Oxidation and Criteria Pollutants, Engine Control and Air/Fuel Ratio Important



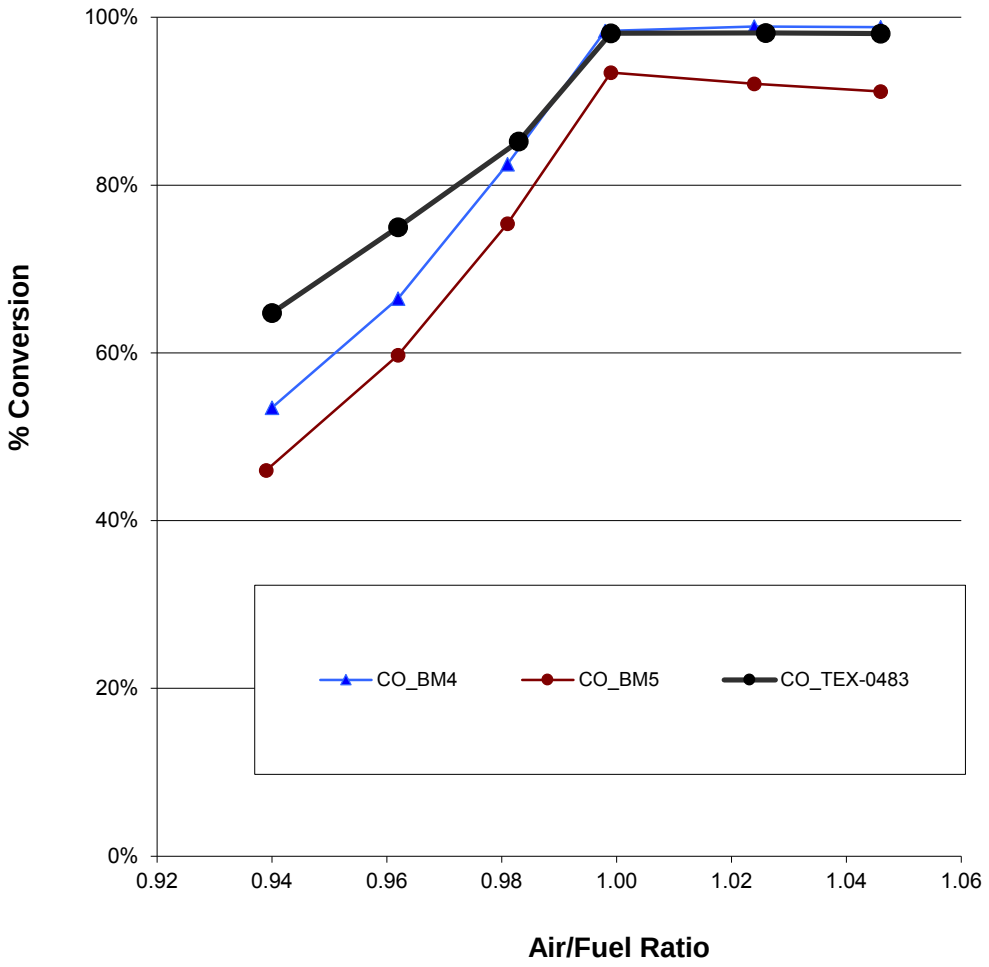
- High temperature stability to 1050C

- 80K/hr SV
- 1” x 2”L, 300 cpsi
- Metal monolith

Reactor baseline

- CO	1.5%
- NO	504 ppm
- NO2	6.0 ppm
- C3H6	2400 ppm
- C3H8	1000 ppm
- H2O	6.0%

Non-Precious Metal Catalyst Technology Can Provide Comparable CO Oxidation to Traditional TWC



- BMC-4 & BMC-5 (no PM)
- TEX-0483 PdRh TWC technology

- BMC High temperature stability 1100C

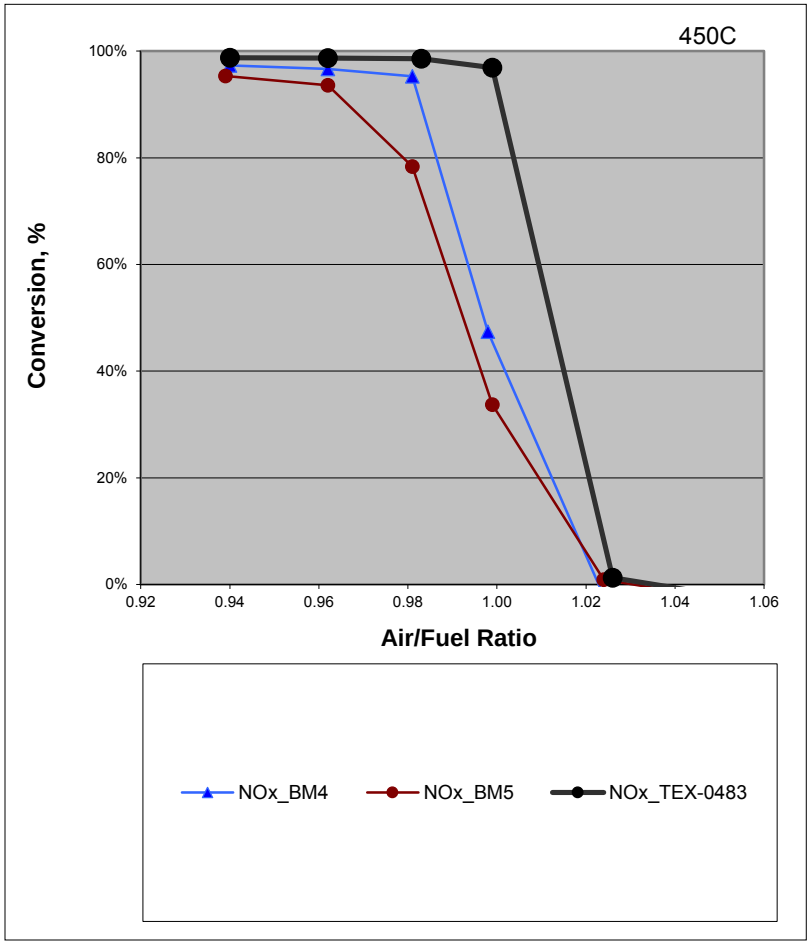
- 80K/hr SV
- 1" x 2"L, 300 cpsi
- Metal monolith

Reactor baseline

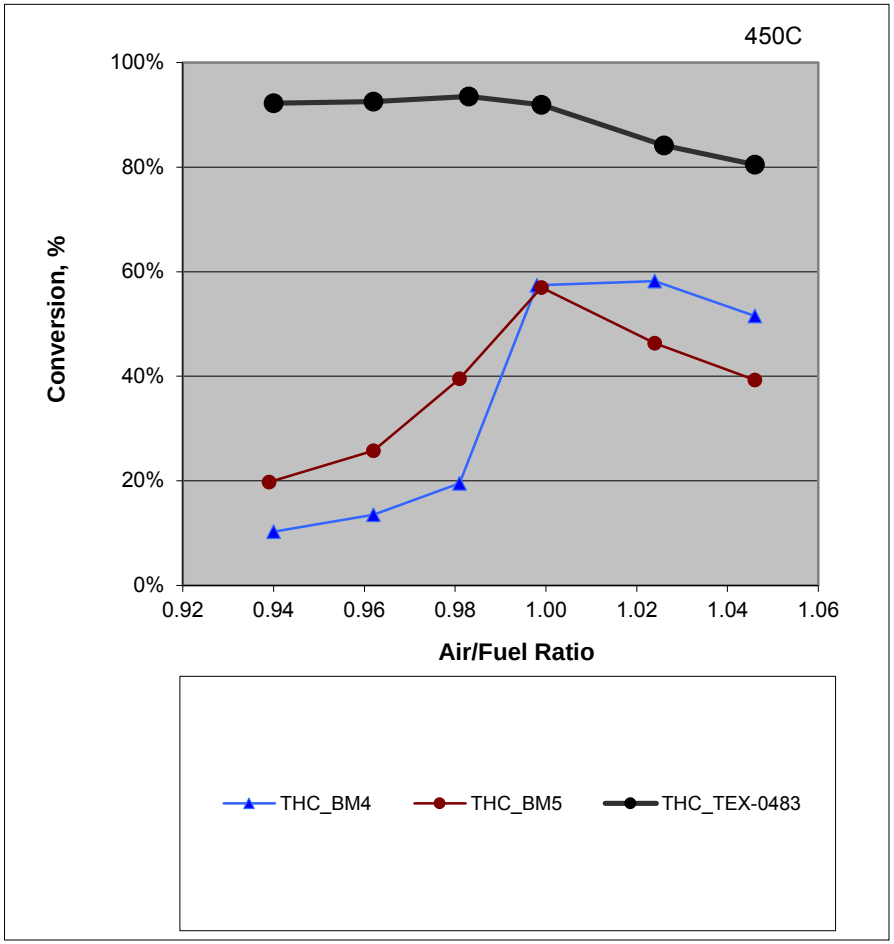
- CO	1.5%
- NO	504 ppm
- NO2	6.0 ppm
- C3H6	2400 ppm
- C3H8	1000 ppm
- H2O	6.0%

Non-Precious Metal Catalyst Technology Has Lower NOx and THC Performance Compared to Traditional TWC

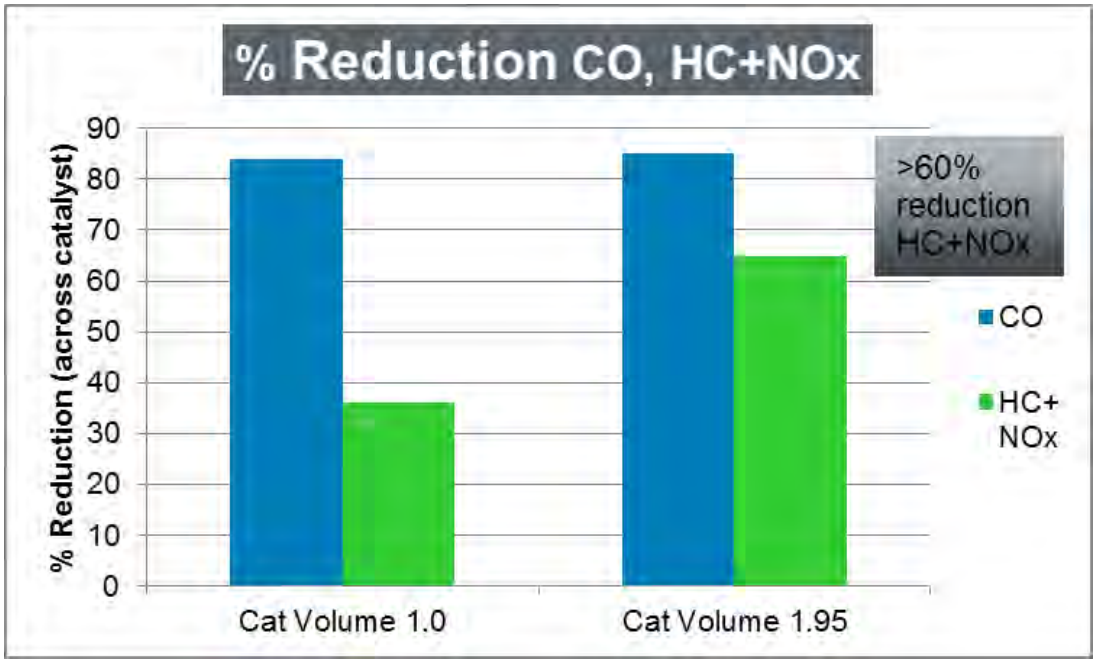
NOx



THC



Catalysts Demonstrate Significant Reductions from Small SI Engines



- Combination of EFI and TWC technology achieves CO, HC, and NOx reduction well below current standards

2012 Consumer Product Safety Commission Study

- "Technology Demonstration of a Prototype Low CO Emission Portable Generator"
  - Closed-loop electronic fuel injection (EFI) with stoichiometric fuel control and three-way catalyst were adapted on engine of commercially available 5.0 kW portable generator (Class II SI air-cooled, single-cylinder, carbureted engine certified to EPA Phase 2)
  - After 500 hours, prototype demonstrated 30% reduction of HC+NOx and 93% reduction of CO compared to unmodified baseline unit

Low CO Nonhandheld Engines Commercially Available

- Over a thousand engines listed in EPA's certification database for MY 2015 nonhandheld engines
  - Approximately 100 engines certified with CO levels less than 50 g/kW-hr
    - Nine engines are gasoline-fueled (four certified to 5 g/kW-hr CO marine generator standard); all use catalysts, and nearly all use closed-loop, oxygen sensor controls
    - Remaining engines are natural gas or propane; some employ catalysts

MY 2015 Nonhandheld Gasoline Engines Certified with Catalysts to Low and Ultra-Low CO

Manufacturer	Marine Generator	Durability (hours)	Fuel Metering	Engine Displacement (cc)	Closed Loop A/F Control	CO Standard (g/kW-hr)	CO Cert Level (g/kW-hr)
Liquid Combustion Technology LLC	No	125	Carburetor	136.0	No	610	47
MiniTruck Certifications LLC	No, small off-road truck	1000	Carburetor	660.0	No	610	46
MiniTruck Certifications LLC	No, small off-road truck	1000	Sequential Multiport Injection	660.0	Yes	610	20
Kohler Co.	Yes	500	Throttle Body Injection	674.0	Yes	5	1.8
Westerbeke Corporation	Yes	500	Multiport Injection	351.0	Yes	5	1.2
Westerbeke Corporation	Yes	500	Carburetor	660.0	Yes	5	0.0
Westerbeke Corporation	Yes	500	Carburetor	1468.0	Yes	5	0.0
Yamagin Corporation	No	1000	Multiport Injection	657.0	Yes	610	45
Vantage Vehicle International Inc.	No, small off-road truck	1000	Sequential Multiport Injection	995.0	Yes	610	35

Ultra-Low CO Marine Generator Engines

Kohler Marine Gasoline Generator – Low CO, Model 10EKD (10 kW, 674 cc)

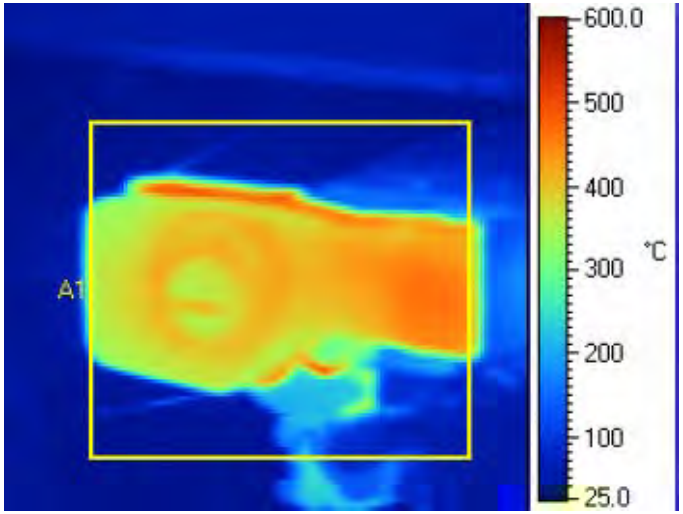
Westerbeke Low-CO EFI Marine Gasoline Generator, Model 3.5 SBCG (3.5 kW, 351 cc)

EPA Conducted Comprehensive Small SI Engine Catalyst Safety Study

- EPA's study focused on incremental risks associated with application of catalysts to Class I and II SI engines
- EPA made use of large CPSC database, industry input, and previous studies to identify key safety scenarios
- EPA's assessment of exhaust catalyst design elements for controlling catalyst heat release and exhaust surface temperatures is consistent with MECA members' extensive small engine experience with catalysts
  - Design parameters included: catalyst size, substrate type, precious metal loading, muffler design, heat-shielding, use of passive air injection, convection cooling
- EPA's test program confirmed catalysts can be designed for small engines to manage exhaust temperatures under all operating conditions without any incremental increase in risk of fire or burns

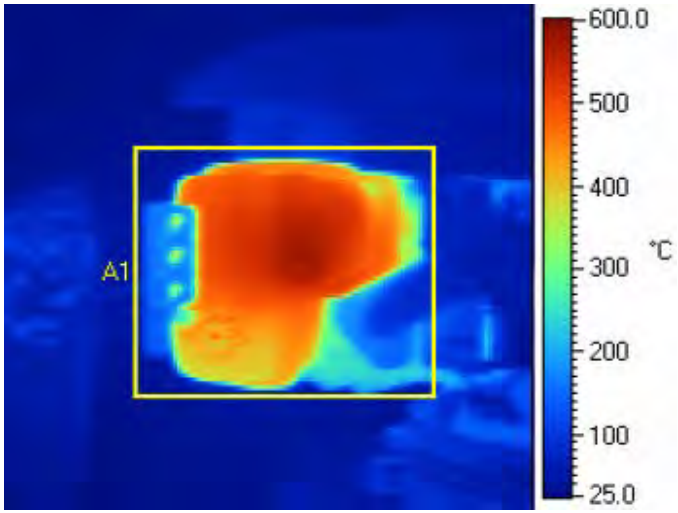
IR Thermal Imaging Showed Cooler Surface Temperatures on Catalyzed Mufflers

Modified Catalyst Muffler, 100% Load



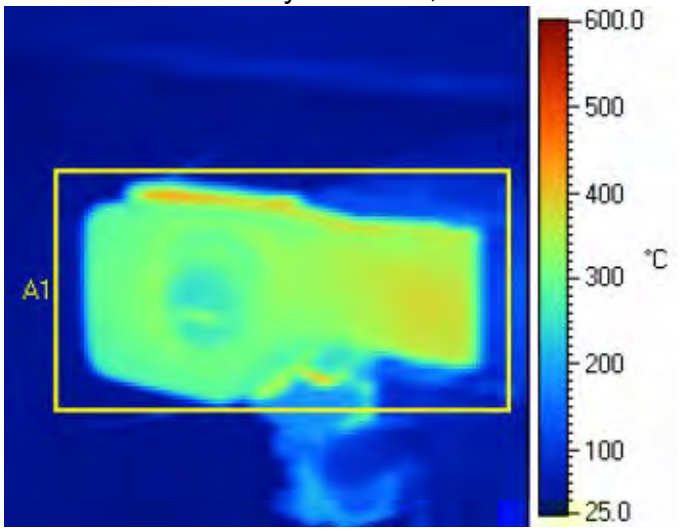
Max. surface temp.: 494.3°C

OEM Muffler, 100% Load



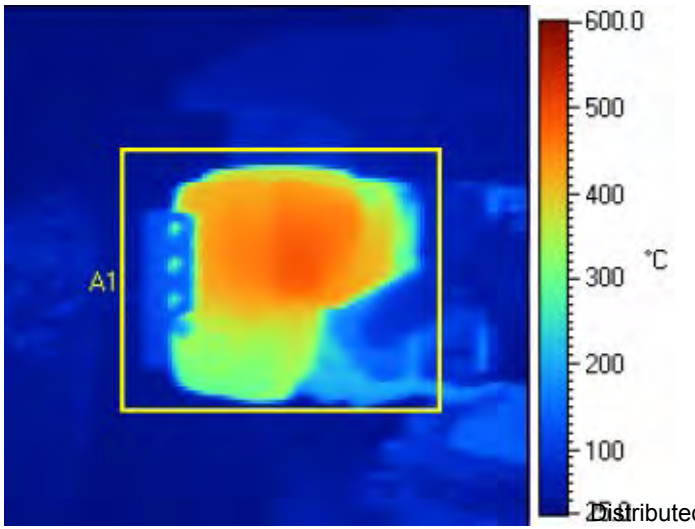
Max. surface temp.: 578.8°C

Modified Catalyst Muffler, 50% Load



Max. surface temp.: 420.6°C

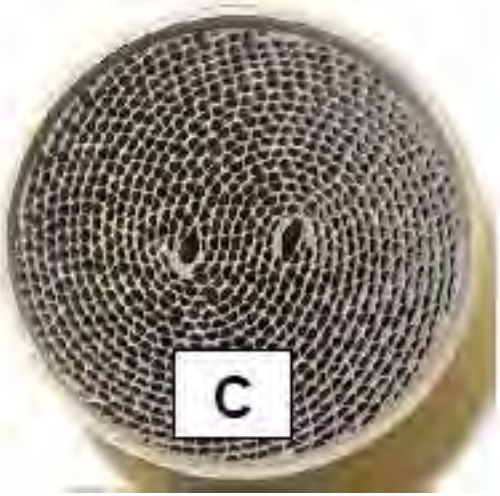
OEM Muffler, 50% Load

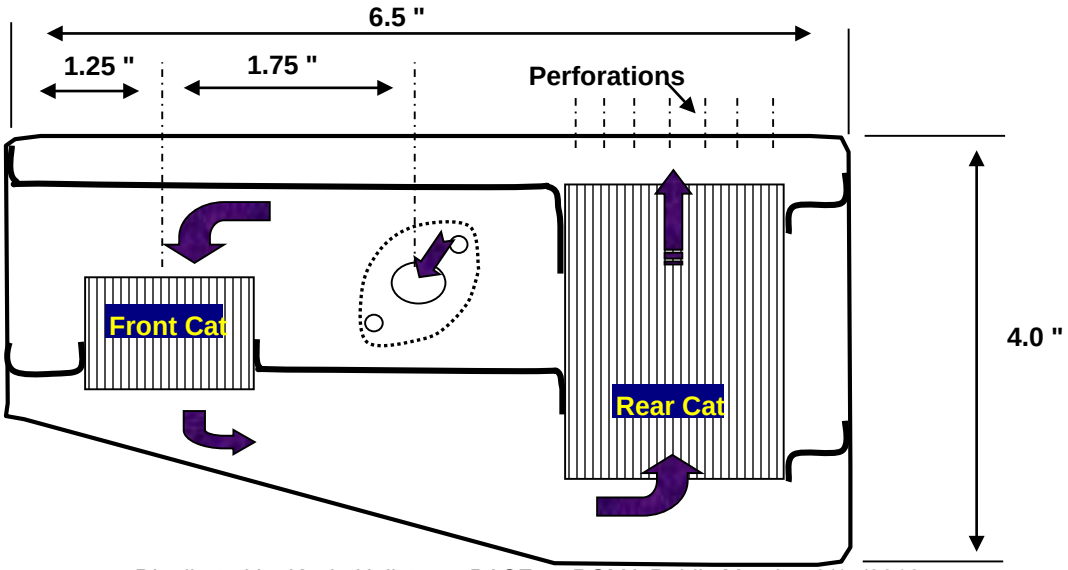


Max. surface temp.: 493.3°C

Distributed by Kevin Hallstrom, BASF at PGMA Public Meeting 9/17/2016

Catalysts Can Be Easily Incorporated into Existing Muffler Housings



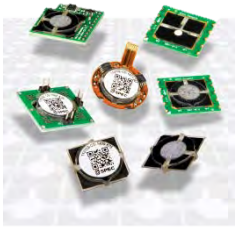


Conclusions

- Small gasoline engines, including handheld and nonhandheld engines such as portable generators, can be engineered to achieve very low CO levels with the help of catalysts
- Catalyst experience for small SI engines draws from over 40 years of experience with catalysts on passenger cars
- Closed-loop control combined with oxygen sensors and secondary air injection along with catalysts can further reduce CO emissions
- CO conversion in excess of 90% has been shown on a variety of four-stroke small gasoline engines
- Catalysts have been safely integrated into conventional mufflers without increasing the exhaust surface temperature

KWJ ENGINEERING INC | INNOVATIVE SOLUTIONS FOR GAS DETECTION

SPEC SENSORS



KWJ ENGINEERING INC.

SPEC SENSORS, LLC

Advanced Solutions for Generator Safety

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Newark, CA 94560
www.kwjengineering.com

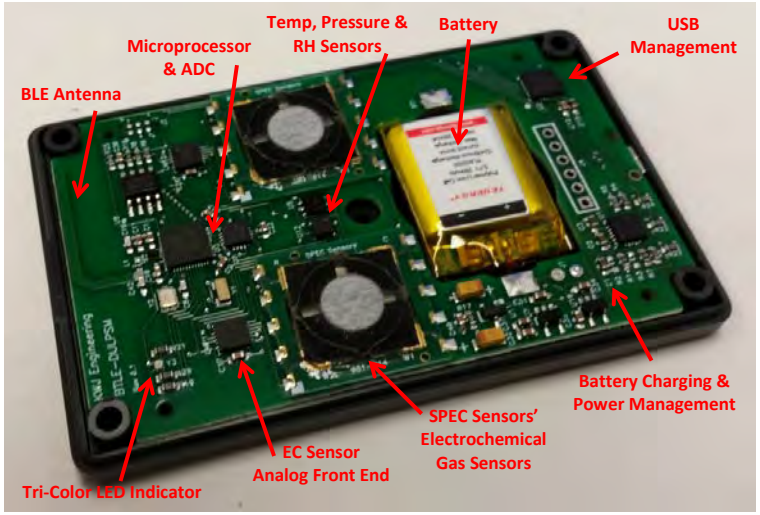
Distributed by Edward Setter, KWJ Engineering, at PGMA Public Meeting 9/17/2016

KWJ ENGINEERING

INNOVATIVE SOLUTIONS FOR GAS DETECTION

Overview

- Innovative Solutions in Gas Detection since 1993
  - Advanced Research and Development in Gas Detection
    - NSF, NIH, DOD, NASA, Private Companies and Institutes
  - ***Custom gas sensing solutions – OEM Provider***
  - Niche market leaders in Carbon Monoxide and Ozone
  - Growth from 10 employees in 2007 to more than 30 today.
- R&D Capabilities
  - Smaller, lower power, less expensive, and ever-more-capable sensing platforms.
  - High performance algorithms, compensation, operating protocol
  - Integration into sensing systems and customer solutions sold worldwide.
  - Wireless and wearable



Product Lines – KWJ

- Eco Sensors – the low cost leader in ozone instruments
  - Broad application for industrial ozone, diverse sensor technology, ambient and dissolved ozone
  - Worldwide distribution

- KWJ In-line OEM
  - CSA Approved 10ppm Alarm for Supplied Breathing Air
  - Low pressue cylinder alarms
  - Pipeline leak detectors

- KWJ Pocket CO
  - Wearable CO monitor
  - High performance in a small, convenient package

- KWJ-WSN
  - Wireless gas sensors for commercial/light industrial, residential
  - Low cost and easy to set up. Long battery life.

SPECSENSORS Overview

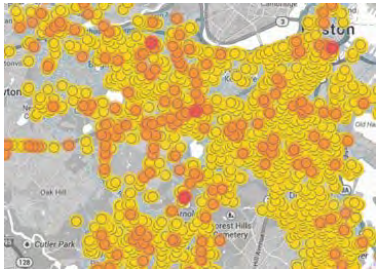
- Founded in 2012 to launch the world's smallest, lowest cost, high performance electrochemical gas sensors

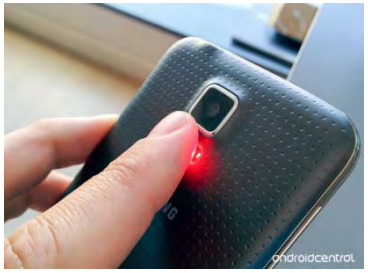
- SPEC Sensors are ultra-low power, ideal for long life battery powered or energy harvested applications

- UL 2034 (& ETL) Recognized Carbon Monoxide Sensor

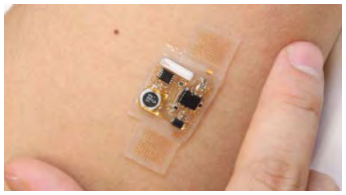
Vision

SENSOR INTEGRATION ENABLES AN EXPLOSION OF INNOVATION…..

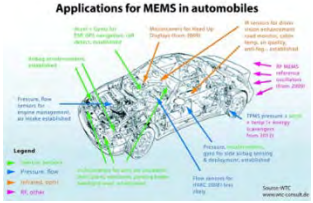




SMARTPHONES DELIVER ENVIRONMENTAL AND PERSONAL AWARENESS



INTEGRATED WEARABLE/INFRASTRUCTURE DEVICES ENABLE PEOPLE



CHEM/BIO SENSORS EVERYWHERE ARE CONNECTED IN A SMART IoE

SPECSENSORS

KWJ ENGINEERING INC
INNOVATIVE SOLUTIONS FOR GAS DETECTION

Increased Capability in Tiny, Low-Power, Efficient Sensor Packages

Industrial – Oil&Gas, Chemicals, Safety, Pharma

- Wireless Sensors and Mesh Networks
- Portable, Distributed, Integrated Systems
- Commercial/Residential Monitors - Legislation

Consumer – Urban Smart Cities, Suburban.

- Demand for Sensors and Smart Systems
- Mobile Health, Safety, Air Quality
- Connected/Smart Home, Car, devices.

Medical – Conformal devices, care, control.

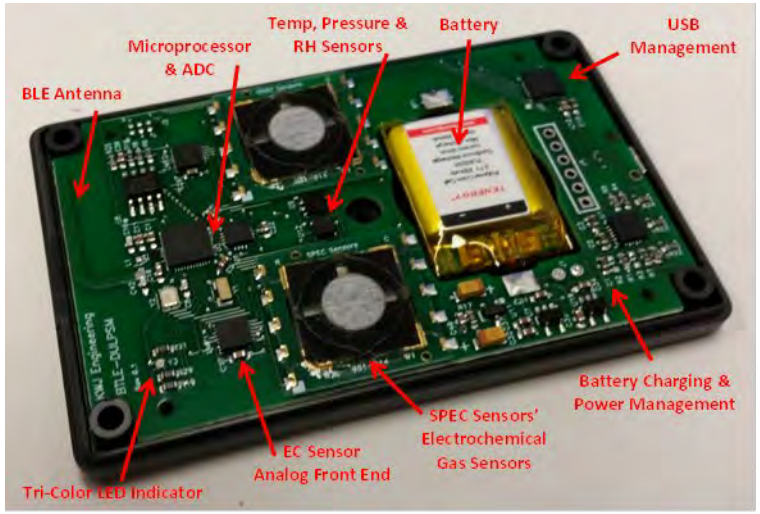
- Flexible, Integrated Systems
- Diagnostics, Breath Analysis
- Patient Monitoring, health status.
- Military, NASA, disaster relief.

SPECSENSORS

KWJ ENGINEERING INC
INNOVATIVE SOLUTIONS FOR GAS DETECTION

KWJ & SPEC Sensors Modular Solutions and Software

- "Smart Sensors" and modular sensor solutions
- Advanced algorithms, compensation methods and data analysis
- Packaging, Manufacturing and Sales



Portable Generators and CO Hazard

- Approximately 1 million generators are purchased in US each year, 90% of those are portable
- Carbon Monoxide is a by-product of combustion
  - Known as the “Silent Killer”, CO is colorless, odorless and deadly
- Generators used indoors or without ventilation cause deadly accumulations of CO
  - PG’s cause 85% of non-fire CO deaths
- Homes, Disaster Sites, RV’s, etc.
- Potential regulation

Health Effects of Carbon Monoxide

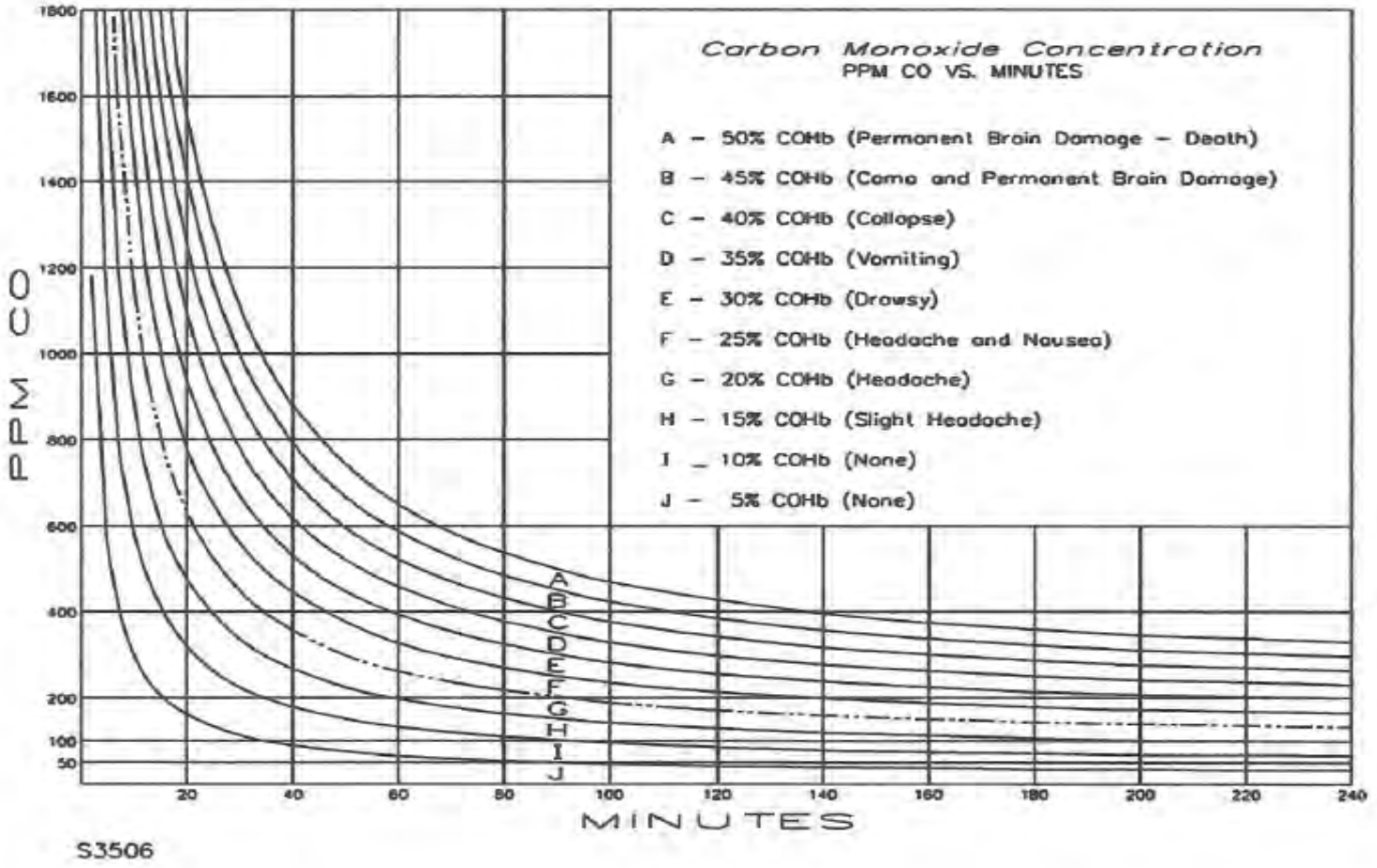
- CO reduces the oxygen carrying capacity of the blood
- High levels cause unconsciousness and death
- Low levels cause health problems in sensitive populations
  - Just 25 ppm can cause fetal brain damage and chronic issues in otherwise healthy individuals
  - 50 ppm is toxic to healthy adults
  - Generators produce 100x more and can deliver these concentrations indoors and outdoors

CO Level	Action
3-7 ppm	6% increase in the rate of admission in hospitals of non-elderly for asthma. (L. Sheppard et al.,Epidemiology, Jan 1999)
5-6 ppm	Significant risk of low birth weight if exposed during last trimester - in a study of 125,573 pregnancies (Ritz & Yu, Environ. Health Perspectives, 1999).
9 ppm	EPA and WHO maximum outdoor air level, all ages, (TWA, 8 hrs) Maximum allowable indoor level (ASHRAE) Lowest CO level producing significant effects on cardiac function (ST-segment changes, angina) during exercise in subjects with coronary artery disease. (Allred et al., Environ. Health Persp., 1991).
15-20 ppm	World Health Organization lists as causing impaired performance, decrease in exercise capability, shortened time to angina response and vigilance decrement.(WHO, 13)
35 ppm	Level which most fire department require that firefighters put on their oxygen masks. Maximum allowable outdoor concentration for one-hour period in any yr. (EPA, ASHRAE)
50 ppm	In healthy adults, CO becomes toxic when it reaches a level higher than 50 ppm.

COHb Levels and Time

Carbon monoxide concentration (ppm CO) versus time (minutes)

Figure 38.1 revised October 15, 1997



Equation For determining estimated percent COHb in blood[a]

$$\%COHb_t = \%COHb_0[e^{-(t/239B)}] + 218[1-e^{-(t/239B)}][0.0003 \div (ppm\ CO/1316)]$$

Need: Sensor Based CO Safety Shutoff

- A standalone device or integrated component consisting of a CO sensor, operating circuit, power source (potentially), and connection to generator
  - Similar devices are used in many other industries such as supplied breathing air, process control, etc.

- Electrochemical CO Sensors
  - Overwhelming choice for CO safety applications and OSHA enforcement
  - Specific to CO (no false alarms), accurate, stable, sensitive, low power
  - Can operate in the field for years in broad range of environments
  - SPEC Sensors combine high performance with small size and low cost

- HMOX CO Sensors
  - Lower cost but less selective, sensitive and accurate
    - Prone to false alarms, interferences from VOC's, fuel vapors, etc.
  - Broader operating temperature range, but susceptible to poisoning from common household elements
  - Higher power consumption
  - Significant non-linear drift with temperature and RH

Configuration and Regulation - Tradeoffs

- Regulations – A Performance Based Standard Needed
  - Goals = Reduce Fatalities (there is no 100% solution)
  - A Shutoff is part of a system that includes warnings, education and other sensors and alarms
  - Use UL 2034 or 2075 as a model

- What level of CO will trigger the shutoff?
  - UL 2034 – warnings start at 30 ppm for 30 days to 400 ppm for 15 minutes
  - NIOSH – 200 ppm evacuation, OSHA – 9 ppm workplace limit
  - Drives the circuit design – complexity can increase cost, but technology and volume reduce cost
    - ASIC's – standards and regulations – See Residential CO

- What environmental conditions must the device work in?
  - What are the scenarios? Extreme heat, dryness, cold for extended time?
  - Are humans always present when the shutoff needs to be operating?
  - Compensation and calibration?
  - UL 2034 & Others suggest -20C to 50C operation, -40C to 70C storage

- How long must it remain in the field?
  - Electrochemical sensors can last 10 years, sealed (battery)
  - Drift allowances for time and environmental conditions - Compensation
  - Survivability vs. Operating Conditions – UL 2034 70C for 28 days
  - **Failsafe and End of Life Testing – UL 2034**
- ***Solution must be reliable, low cost, long life, high volume…***

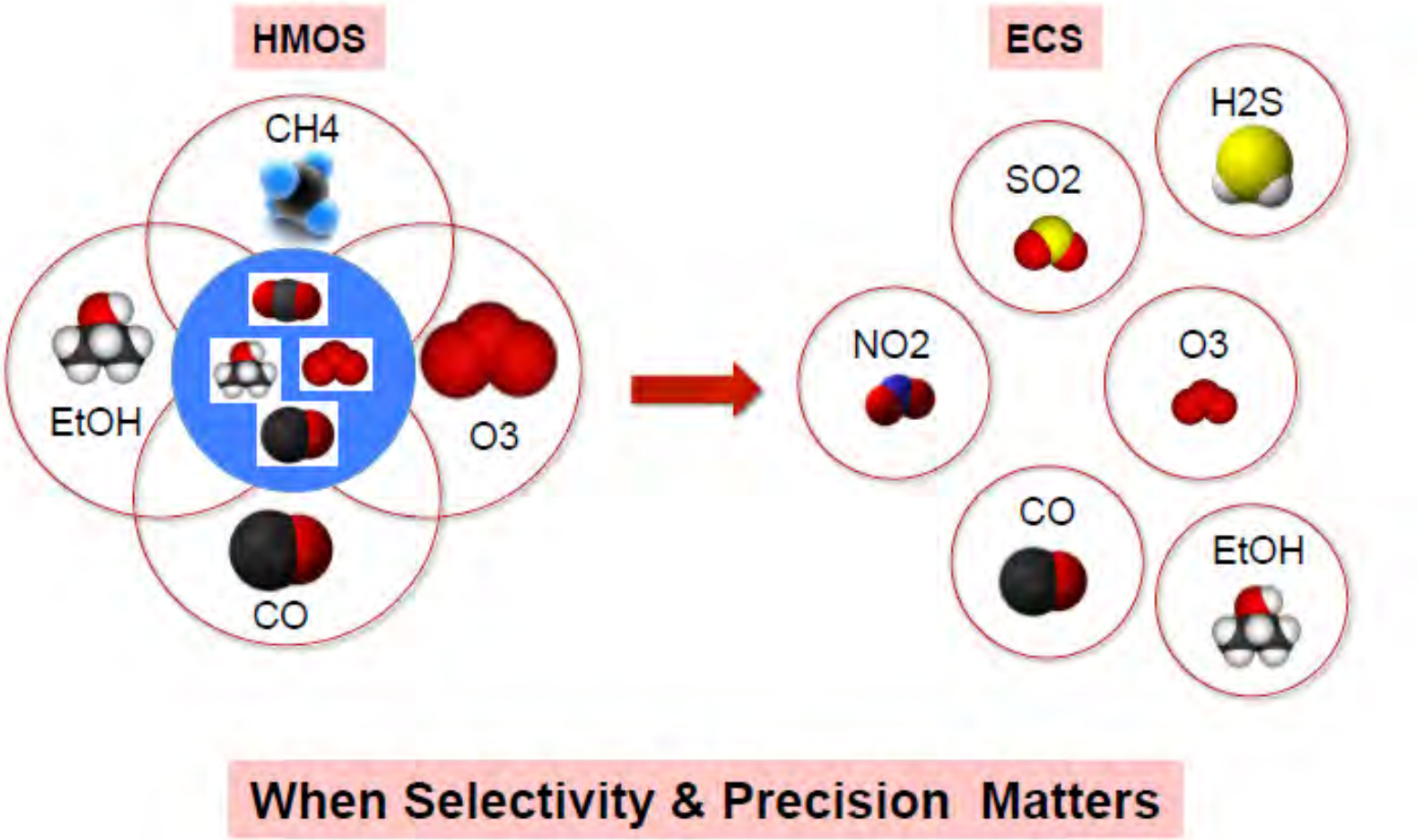
Alarm Levels – Performance – UL 2034

- UL 2034 defines performance specifications for residential, RV and Marine CO Alarms
  - Operating and storage temps, accelerated lifetime testing, accuracy by % error
- Requires MTBF, End of Life Test (in device)
- Technology's impact on the standard

Table 38.1
Carbon monoxide concentration versus time for alarm test points based on 10 percent Carboxyhemoglobin (COHb)
Table 38.1 revised November 14, 2001

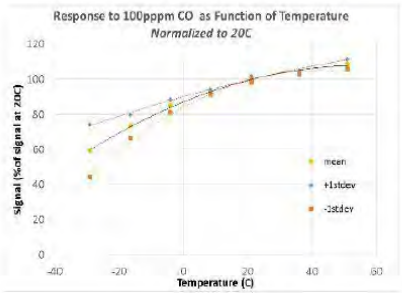
A. Carbon monoxide concentration and response time	
Concentration, ppm	Response time, minutes
70 ±5	60 – 240
150 ±5	10 – 50
400 ±10	4 – 15
B. False alarm – carbon monoxide concentration resistance specifications	
Concentration, ppm	Exposure time, (no alarm)
30 ±3	30 days
70 ±5	60 minutes

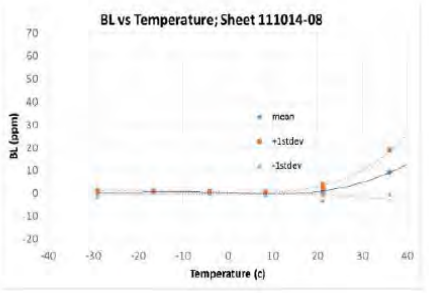
Metal Oxide vs Electrochemical

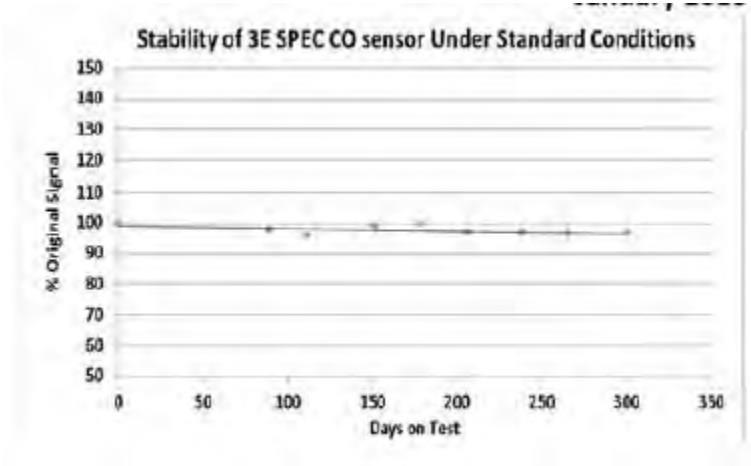


Drift, Accuracy and Lifetime

- All environmental sensors drift with time and environmental conditions
  - EC sensors can be compensated for T and RH effects
  - Zero drift in stable conditions is nominal %
  - Drift in changing conditions is cyclical
  - Compensation and zero adjustment protocol used in the field
- Sensors can be destroyed by long term exposure to EXTREMES
  - Temp, P, RH or chemicals/gases
  - These sensors are currently used in very harsh environments and relied on by safety professionals for 50 years
- SPEC CO – UL 2034 Recognized
  - 70C for 28 days
  - 0 to 50C operation
  - -40 to 70 C storage

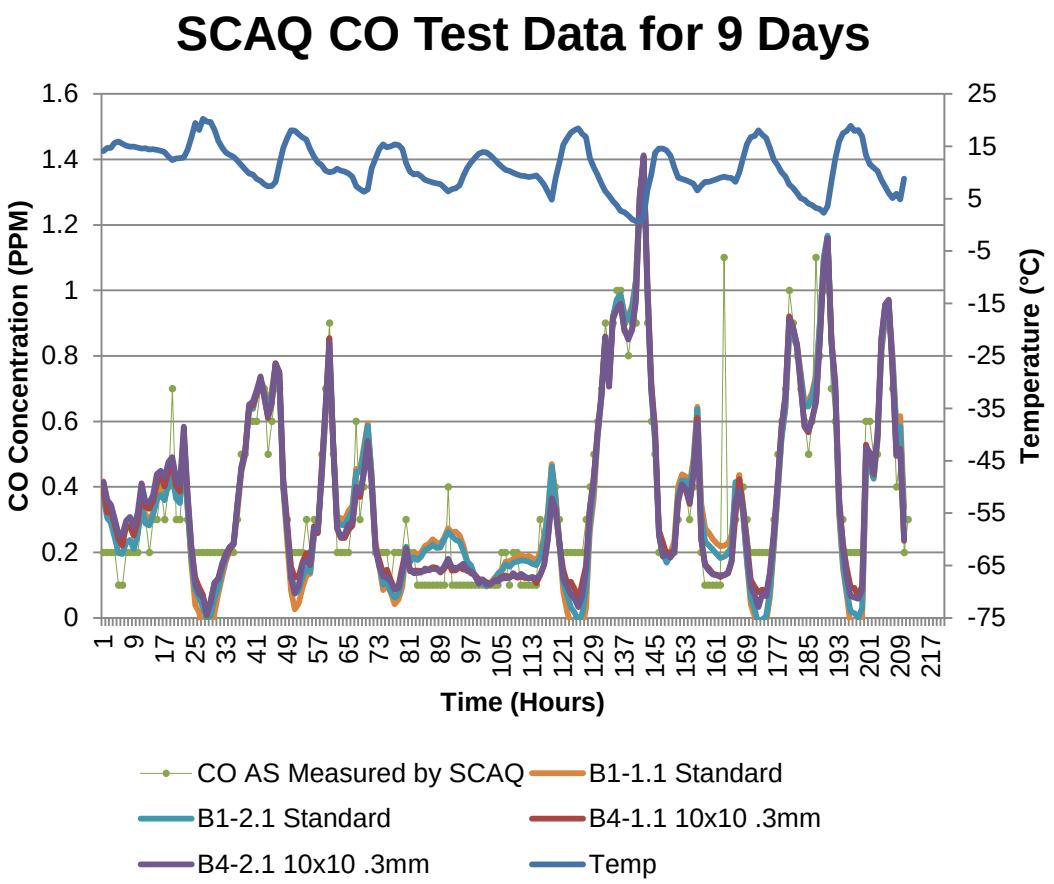






CO Data From Outdoor Test

- 3rd party test against EPA reference analyzer, outdoors
- >90% correlation to reference
- Accuracy, stability at 100ppb!



SPEC Sensor Based Solution for CO

- Small, High Performance, Low Cost SPEC CO Sensor with operating circuit and generator switch control
  - CO Sensor is UL 2034 Recognized
  - Circuits are ultra-low power and have been deployed in life safety applications for many years (5-10 years on battery)
  - Commercial deployments with RF Energy Harvester
  - Develop low cost enclosure for proper air flow and environmental conditions

1. Analog Solution – Lowest Cost
   No battery needed
2. Digital Solution – Higher Performance
3. Wireless Solution – Value to Consumer
4. Energy Harvested – RF – The Future

1.  20x20x5mm

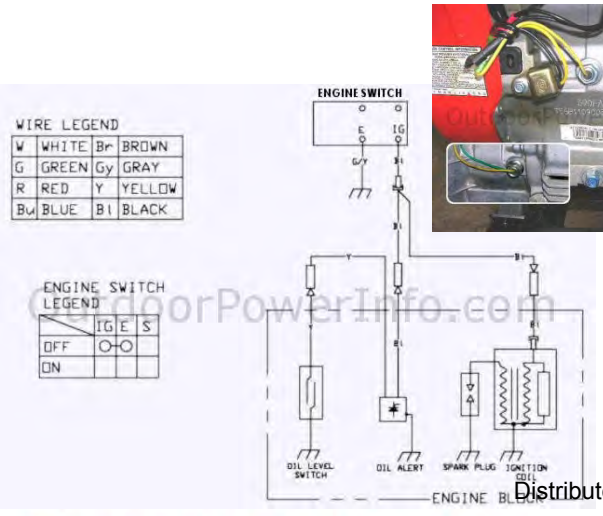
1.A 

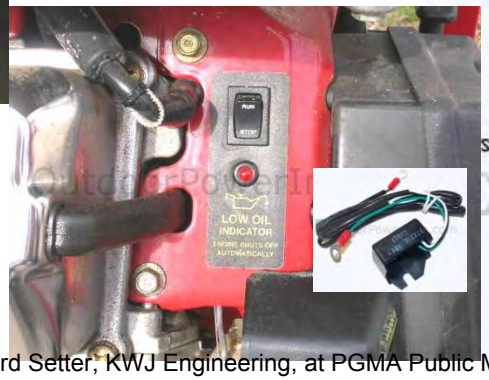
2-3 

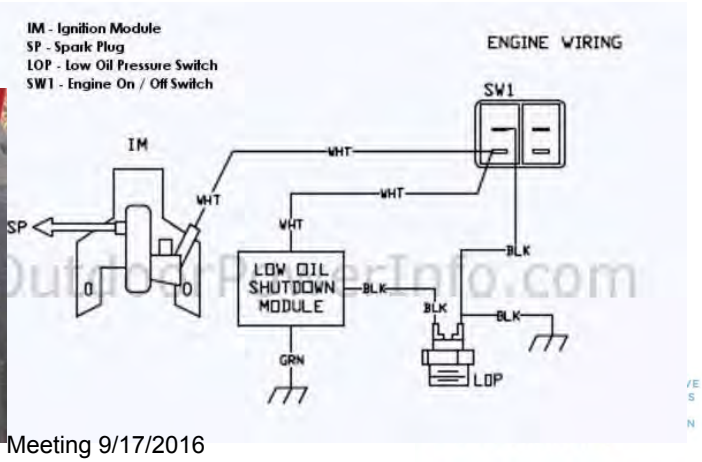
4. 

Sensor Solution Based on Low Oil Shutdown – 2 wiring options

- CO Shutoff Module mounted in an appropriate location, connects to an indicator light, the primary winding of the ignition coil, and to the engine run/stop switch.
- If the CO shutoff module engages due to a high CO level:
  - The ignition primary is grounded to the engine block and the engine stops running
  - CO is no longer being produced but may still exist at dangerous levels - recovery
  - The indicator light illuminates, warning the user of a potentially dangerous situation
  - Audible alarm could also be integrated
  - End of life operating test should also be incorporated
- CO Shutoff Module could be an aftermarket add-on or an integrated OEM component.







Conclusion

- Portable generators need a CO safety device
  - Must be reliable, low cost, long life, high volume
  - Partnerships and consortiums are needed to define and develop a solution
- KWJ Engineering and SPEC Sensors CO Solution
  - Advanced sensor technology can be configured to meet a wide range of potential solutions
  - KWJ can supply OEM solutions and Direct to Market
  - We have IoT and Energy Harvesting solutions for the future
- SPEC Electrochemical Sensors are the choice for CO safety
  - Electrochemical sensors have been the choice of OSHA, EPA, and Home Safety for decades
  - They have been deployed in some of the harshest environments in the world
  - SPEC Sensors are UL 2034 recognized
- CO Health and Safety starts at low levels
  - Sensor performance is essential in this application – the difference between life and death

6 Recommendations for Preventing Carbon Monoxide Poisonings and Deaths Caused by Portable Generators

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Env. Health Engineer and
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PGMA Technical Summit on CO
BWI Airport Marriott Hotel
March 17, 2016

Disclosures

Mr. Donnay
* consults on CO issues for clinicians, poisoning survivors, government agencies and detector manufacturers

* has 3 patents pending related to the testing, treatment and prevention of CO poisoning from which he does not yet earn any income.

* first recommended a CO shutoff switch to PGMA's Technical Standards Committee in 2012

Problem 1 Methods tried by CPSC and PGMA to reduce CO deaths and poisonings from portable generators are not sufficient

a. Mandating CO Danger Label
on PGs and in manuals (from 2007)

b. Promoting CO Awareness via PSAs
Safety First in 2013
Take it Outside in 2015

c. Promoting new CO specs via Voluntary UL & PGMA Standards

d. Publishing Advance Notice of Proposed Rulemaking in 2006

e. Researching technical solutions starting in 2004 including:
interlocking engines with CO shutoff devices *(before ANPR)*
making engines with lower CO emissions *(after ANPR)*

Solution 1: Just as most Portable Generators have Automatic Shutoffs *to protect their engines* from being harmed by low oil,

All should also have an Automatic Shutoff *to protect their operators* from being harmed or killed by high CO

Fail-safe designs should be built into new PGs and offered as a 2-wire retrofit for older PGs.

CPSC Support for Automatic CO-Sensing Controls

CPSC staff have tested and validated that CO shutoff devices work

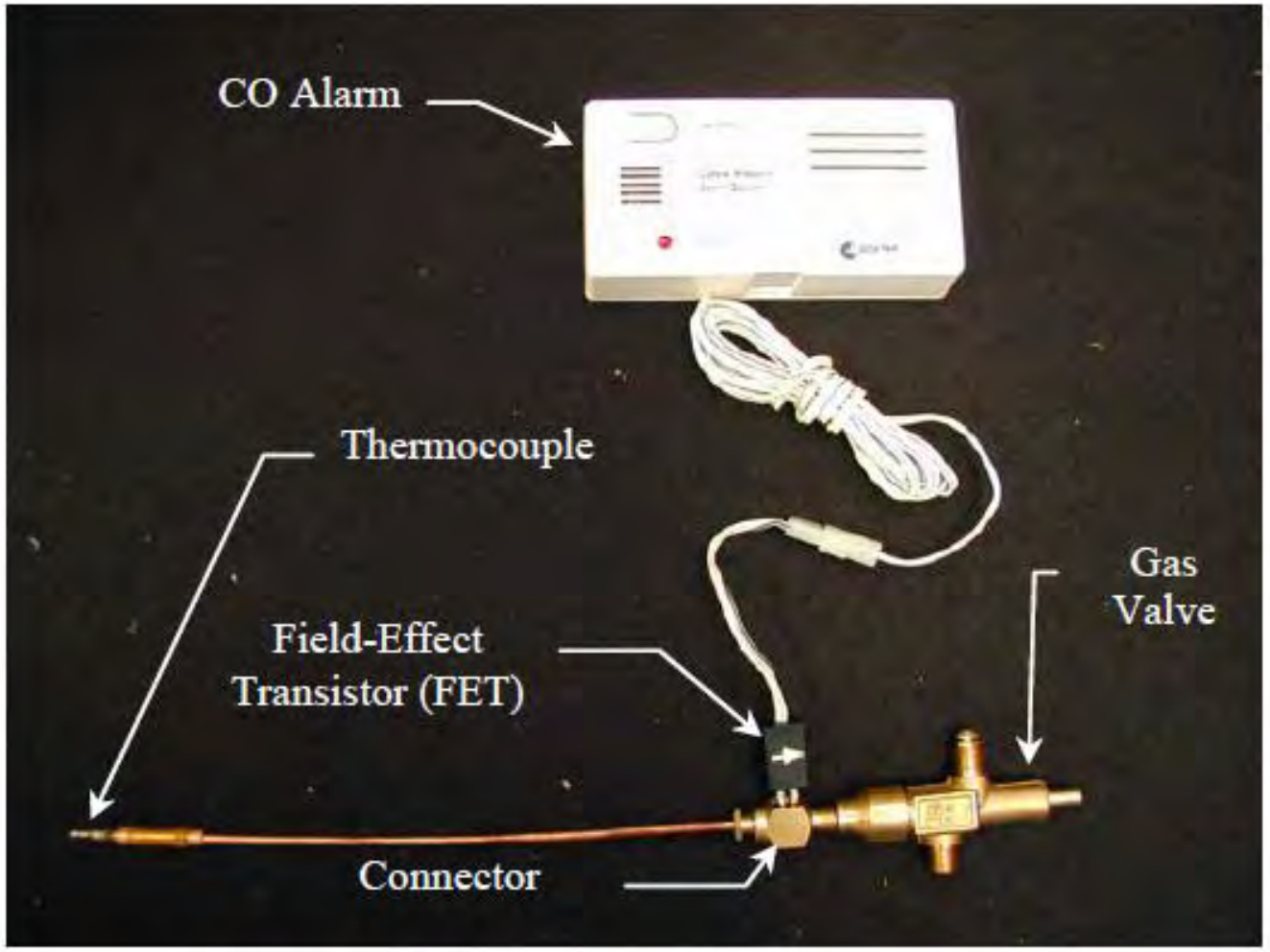
For Gas Furnaces: Ronald Jordan has been promoting CO-sensing shutoff devices for furnace flues to CSA/ANSI Z21.47 since 2000, to trip furnace if 15-minute average of CO in flue exceeds 400ppm

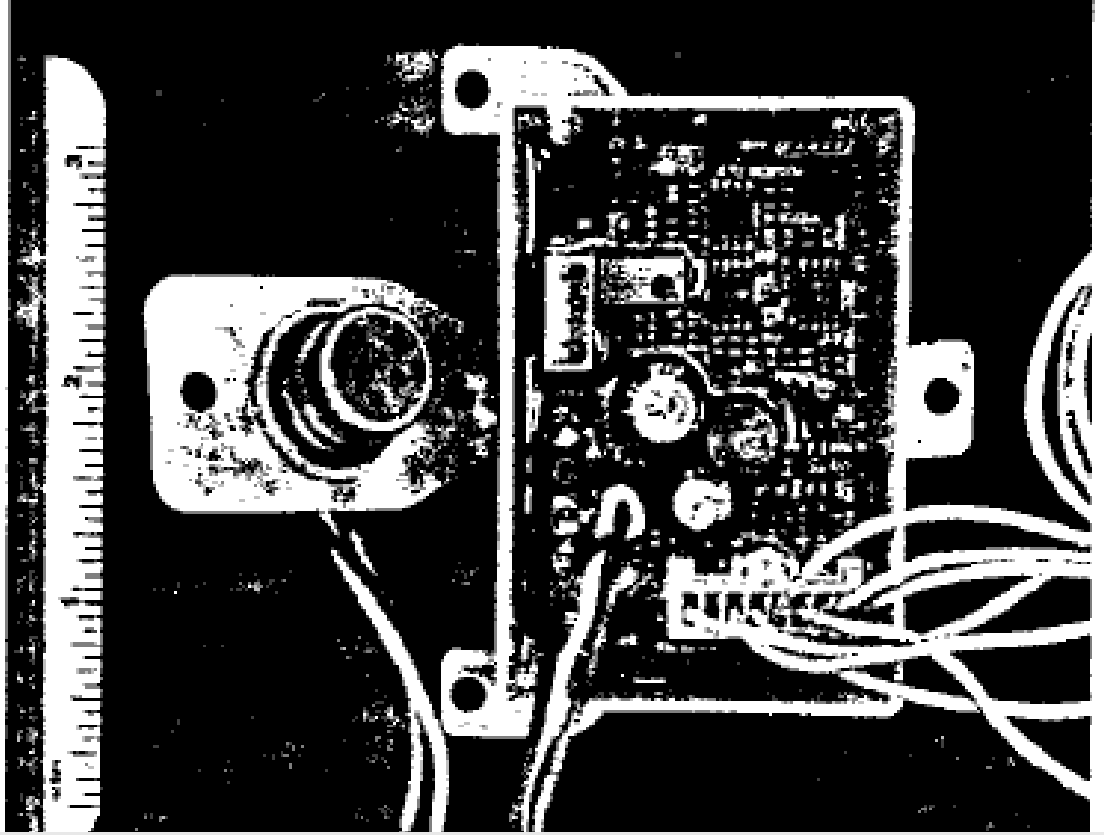
For Propane Tank Top Heaters: David Tucholski reported in 2005 on the "Technical Feasibility of a CO Shutdown System for Tank-Top Heaters"

For Portable Generators: Chris Brown reported in 2005 that home CO alarms hardwired to a PG could stop the engine faster than wireless CO alarms located remotely, both indoors & out, and without false alarms.

CPSC staff reported these findings to the Commissioners in 2006 but did not finalize this report until 2008 and only released it in 2013

CO-Sensing Controls Tested and Validated by CPSC Staff





Sources = Jordan 2001 , Tucholski 2005, Brown 2008

Industry Support for Automatic CO-Sensing Controls

Although not tested or mentioned in CPSC staff reports, automatic CO controllers are widely used:

In commercial parking garages since the 1980s
to turn exhaust fans on/off as UBC 705 & IMC 403.5 require
>$100 each due to local buyers needing only small quantities

In vehicles with electronic climate control since the 2000s,
to open and close fresh air inlets in response to outdoor CO
<$10 each due to global commodity market (>35M cars/yr)

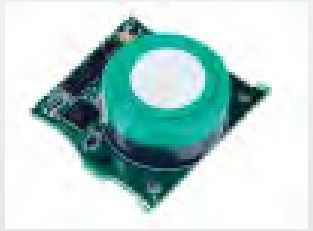
CO controllers are not just for garages

*** Boiler Rooms, Generator Rooms, Mechanical Rooms**
*** Tunnels * Ice/Hockey Rinks * Bus Terminals**
*** Car Dealerships * Service Bays * Sally Ports**
*** Hospitals * Factories * Warehouses**

4.3x2.2x3

Conspec (and many other) features

- Electrochemical Sensor (*needs regular calibration*)
- Fail Safe Operation
- Microcomputer Self Tests Electronic Circuitry
- Bright LED Display for Power, Fan Activation, Alarm Status and Sensor Fail
- OSHA Compliant; Los Angeles City Approved
- Automatic Restart After a Power Interruption
- Automatic Reset when Alarm Condition Clears
- Rugged NEMA 4-4X Weatherproof Enclosure



4.5x2.75x2.2

Automotive “Air Control Modules”

metal oxide CO+NO2 sensors last >10 years and never need re-calibration

Manufacturers include:

Bosch
Casco
City Technology
Denso
Johnson Electric/SAIA-Burgess
Kostal City Technology
Figaro Engineering
Paragon
SGX SensorTech

Performance specs for Air Control Modules

SCOPE OF LIFE TESTING

12,000 Operating cycles

54,000 ON/OFF cycles

22 hour Vibration test

21 different Wetting tests

Shock and Drop tests

* Detects CO from as low as 10ppm
* Accuracy = +/-10% to +/-20%
* Response time = 1 to 3sec at 25C
* Air speeds = 0.5 to 10 m/s
* Operating Temp = -40 to +80C
* Relative Humidity = 10 to 95%
* Leak proof to dust, water and fog
* 2 year warranty but 15 year design life

Location, Power and Wiring of CO Shutoff in PG

as prototyped by CPSC staff in 2005 with 4 home CO alarms on 1 PG

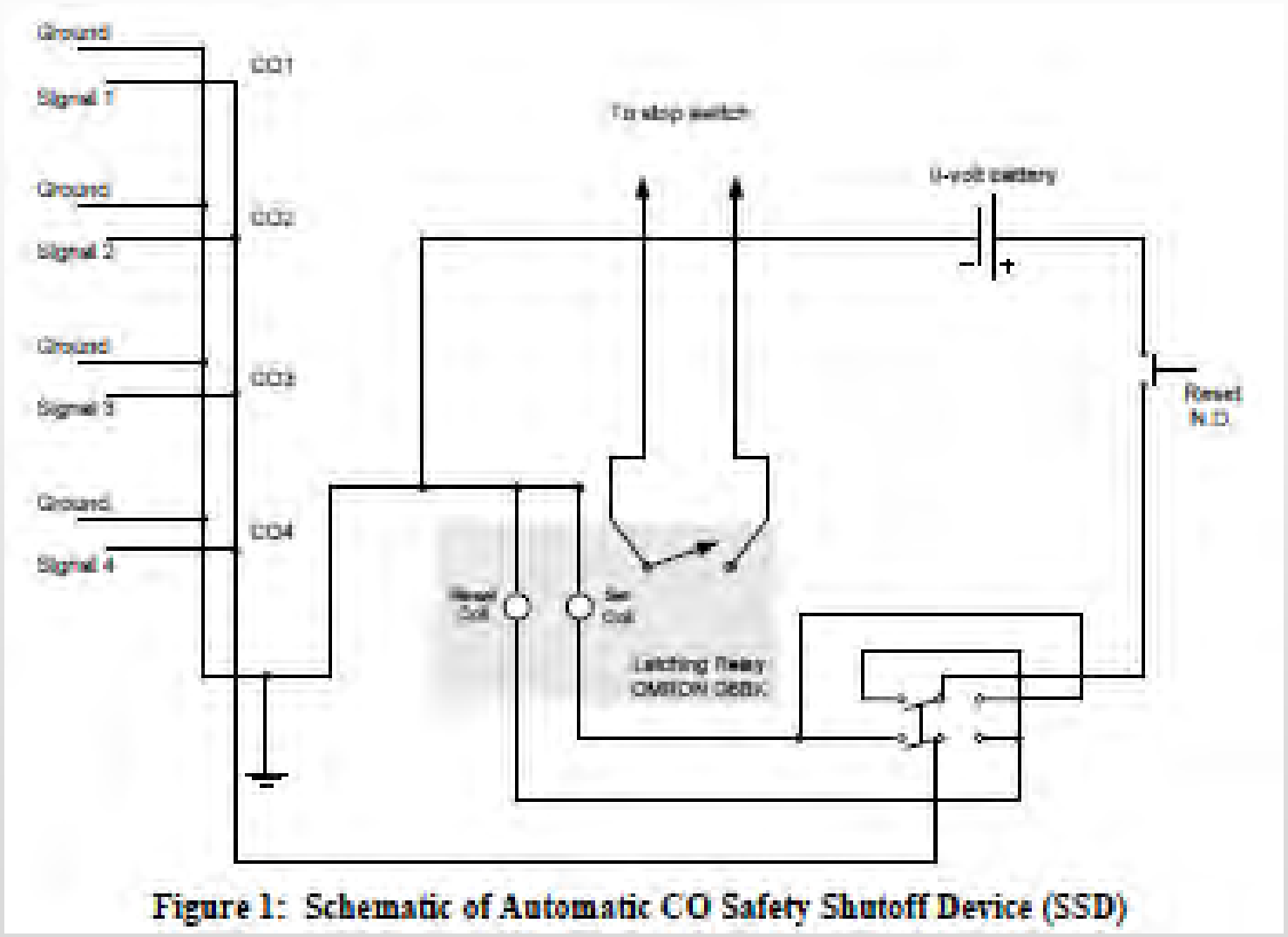


Figure 1: Schematic of Automatic CO Safety Shutoff Device (SSD)

Source = Brown 2008

CO sensors are not needed on top of PG or all sides

Preferred location: same side as exhaust &facing same direction
so it can quickly detect CO buildup that may occur when exhaust flow:
a) is obstructed, b) too close to a wall, or c) improperly aimed upwind.

Power: replaceable or rechargeable battery,
and/or by 12v DC or 120v AC from portable generator.

Wiring: splice into existing PG circuit from oil sensor to shutoff;
and attach second wire to the frame ground fastener.

Wiring Options for CO Shutoff on Portable Generator

Source = MainBlind at
www.youtube.com/watch?v=6esHkPyygWw

CO Alarm & Shutoff Levels for Portable Generators

CO Alarm

Instead of tone, loop loud bilingual message “Take it Outside”
when 3 consecutive CO measurements exceed some rational limit:

25ppm = lower limit for Garage Fans per Intl Mechanical Code 403.5

50ppm = lower limit for Garage Fans per Uniform Building Code 705

70ppm = lower limit for Home CO Alarms per UL, CSA and NFPA

200ppm = lower limit for Workplace CO Evacuations per NIOSH

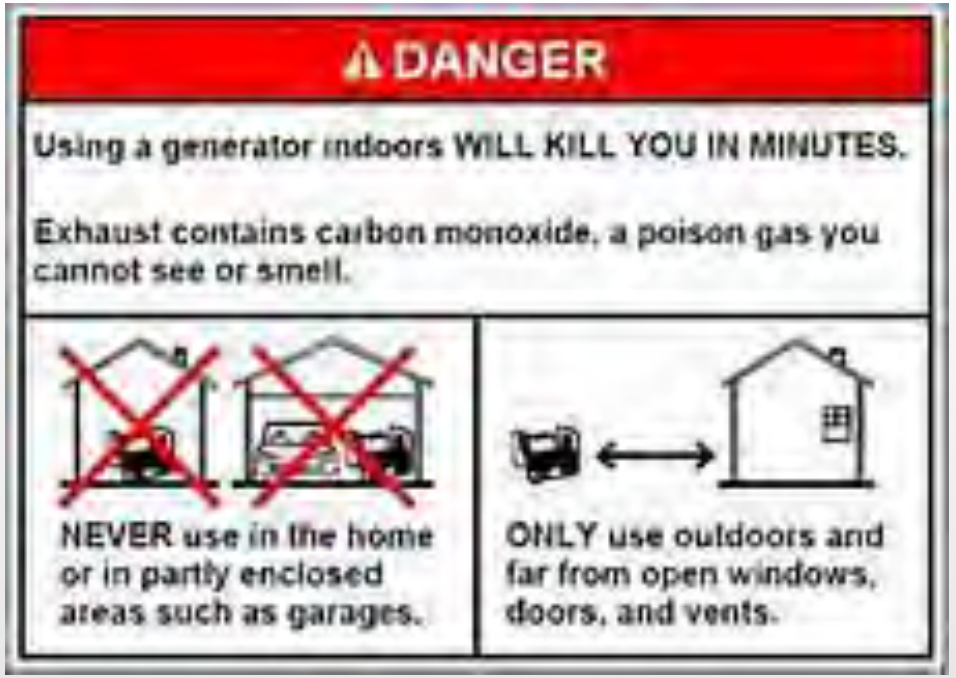
CO Shutoff

Trip engine when 4 consecutive CO measures exceed alarm limit and then block re-start until CO is well below this same limit.

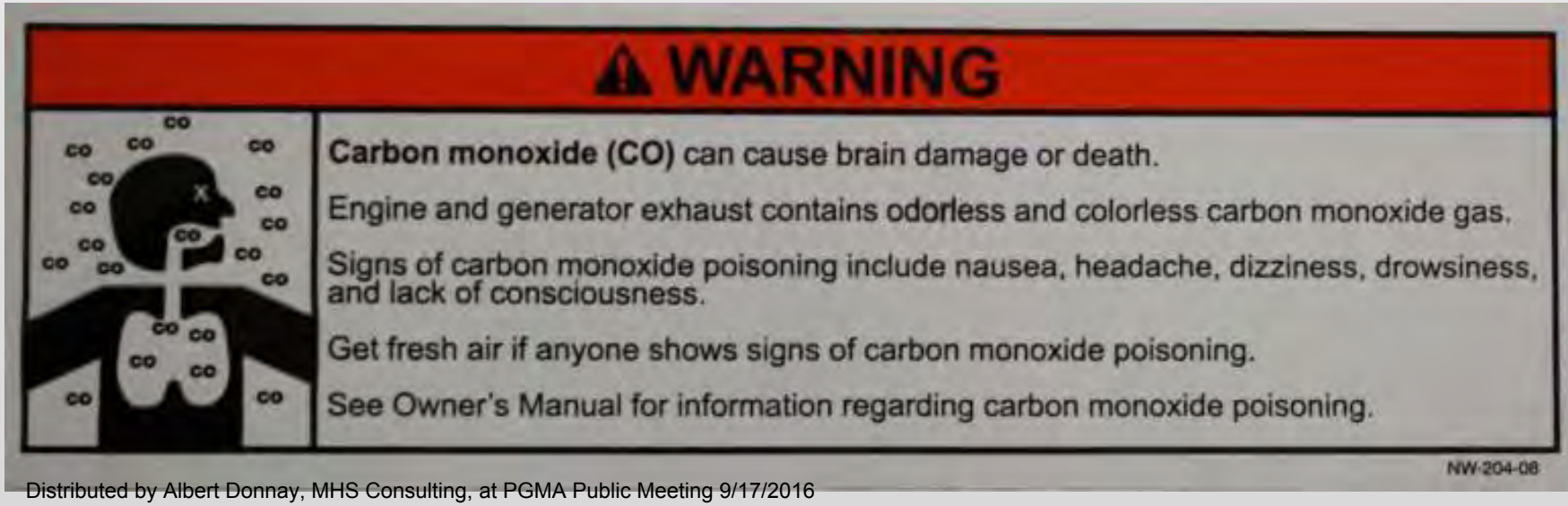
No time delays should be added to any CO alarms or CO shutoffs since delays needlessly extend the duration of CO poisoning.

Other CO-Related Safety Recommendations

Problem 2: All PG makes and models (and manuals) include the red DANGER label about CO risks required by CPSC but many also have an orange WARNING label about CO that is not required.



Solution: Remove all the orange WARNING labels or change title to red DANGER.



Problem 3: Most PG models do not highlight location of deadly exhaust outlet, although they do identify hot surfaces

Solution: Paint end of PG exhaust pipe, muffler, or spark arrester **BRIGHT RED** and affix the universally recognized Skull & Crossbones **DANGER** symbol next to the exhaust opening.

Problem 4: PGs are not designed for use in rain.

Solution: Weatherize outlets with a hinged plastic cover, like portable welders.

Problem 5: Many fires are started by people trying to refuel PGs while engine is running.

Solution: Add a contact sensor in the gas tank cap so the engine trips and locks out when the cap is loose or removed.

Problem 6: Even when portable generators are used outdoors, lethal levels of CO may build up indoors if doors or windows are cracked open to accommodate extension cords. Doing this also may damage the cords, increasing risks of shock and fire.

Solution: Sell generators with a user-adjustable device designed to:

1. ***Allow electric cords to pass flat under open windows***
2. ***Keep generator exhaust outdoors***
3. ***Keep electrical strips indoors***
4. ***Stop drafts and keep out insects***
5. ***Reduce generator noise heard indoors***

Could be attach to frame when not in use

Could sell as aftermarket accessory to owners of older generators

Summary [PDF at www.tinyurl/DonnayPGMA]

1. Both CO poisonings and deaths from portable generators can and should be prevented by linking engines to automatic CO controllers.
2. Reducing the CO level emitted by PGs may reduce but will not eliminate CO deaths and may result in more CO poisonings if widely advertised.
3. CO poisonings and deaths also may be reduced by
   a) harmonizing CO labels so they emphasize DANGER not WARNING
   b) painting exhaust outlets bright red so they are clearly visible to users
   c) adding weatherproof covers to receptacles so users are less tempted to run generators indoors or under awnings
   d) including devices that allow electric cords to be run flat under windows without damaging them while also blocking exhaust and drafts